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Miſs Meek

ANALYSIS
OF
A COURSE OF LECTURES
IN
NATURAL and EXPERIMENTAL
PHILOSOPHY.

VIZ.

1. PROPERTIES OF MATTER,
2. MECHANICS,
3. CHEMISTRY,
4 & 5. PNEUMATICS,
6. HYDROSTATICS,
7. ELECTRICITY,
8. ELECTRICITY,
9. OPTICS,
10. USE OF THE GLOBES,
11 & 12. ASTRONOMY, &c.

BY

A. WALKER.

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ADVERTISEMENT.

As many who attend this Courſe may not have made PHILOSOPHY a *previous ſtudy*, it may be ſuppoſed that many of its uſeful parts will eſcape the memory; 'tis therefore at the requeſt of *thoſe* I have drawn up this Analyſis, by a ſhort look at which, any particular propoſition or experiment will eaſily be recollected.

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ANALYSIS

OF

A COURSE OF LECTURES

ON

NATURAL AND EXPERIMENTAL

PHILOSOPHY.

LECTURE I.

On the general Properties of Matter.

AN hundred and fifty years are ſcarcely elapſed ſince the clouds of prejudice, which had long overſpread the world, began to clear up, and men were convinced, by cultivating the ſciences and attending to Nature, that no *fanciful conjectures* could ever lead them to the true cauſes of thoſe various phænomena that inceſſantly, and every where, meet the obſerver's eye; and that the narrow limits of the human underſtanding, confine the courſe of our reſearches to *one ſingle path*—namely, that of *experiment*, or the *uſe of our ſenſes*. Yet in this ſhort period, Natural Philoſophy hath ariſen to an high pitch of improvement; and may with truth be ſaid to have made much greater advances towards perfection ſince the experimental method was introduced, than in the many ages before.

Becauſe many bodies are reducible to water, *this* element has been thought, by many able philoſophers, to be the primary origin of all matter; and that bodies differ only as they contain more or leſs *particles* or *pores* differently diſpoſed. We find, indeed, the decompoſition of bodies, finite; being unable to carry it beyond a certain limit; if we attempt to go further, we are always ſtopt by ſubſtances in which we can produce *no change*, which are incapable of being reſolved into others, and which ſtand as ſo many *firm barriers* obſtructing our progreſs. Theſe ſubſtances, or principles, have been generally pronounced to be *earth*, *air*, *fire*, and *water*, though it is well known, that *water* can be formed by inflaming hydrogen and oxygen gas in a cloſe veſſel, and modern Chemiſtry has adopted ſeveral other elements.

Whatever the elements of matter may be, the particles of that matter are conceived to be infinitely diviſible; too ſmall to be ſeen, though magnified by the moſt powerful optical inſtruments. A candle will put in motion a ſphere of light of four miles in diameter, in a ſecond of time. Two ounces of aſſa-fœtida, nicely weighed, may lie expoſed to the air, and have its particles carried off by it for a fortnight together, and yet it will not loſe a thouſandth part of a grain of its original weight. One pound of gold is capable of covering a wire of ſilver that will circumſcribe the globe. A grain of copper diſſolved in a gill of diluted aqua fortis, will cover as much poliſhed iron with a fine ſkin of copper, as the aqua fortis will wet. Nay, Lewenhoeck diſcovered with his microſcope, more living animalculæ in the milt of one cod-fiſh, than there are men, women, and children, on the whole earth.

2dly. The matter of which theſe elements are formed is *impenetrably hard*. If we pound the moſt brittle ſubſtance to the moſt impalpable powder, its original particles ſtill remain unhurt. If water has no bed of air to fall upon, it will fall upon the glaſs in which it is encloſed like a piece of iron, and make a loud click; a column of air falling on the plate of an air-pump, will give a report as loud as a gun: Nay, elementary fire, ſubtil as it is, ſtrikes the bones, in the electric ſhock, like a ſolid body; and lightening penetrates the hardeſt ſubſtances.

3dly. Matter is *inert*, *i. e.* can neither move, nor ſtop, of itſelf. A ball on the whirling-table, neither begins to move when the table moves, nor ſtops when the motion of the table is ſtopped. Give a ſudden puſh to a bowl of water, and the fluid will fly over the bowl in a contrary direction; if you run ſwiftly with the bowl in your hand, and ſtop ſuddenly, the water will fly over the bowl the way it was going. The *inertia* increaſes as the quantity of matter. A man lying with a large anvil on his breaſt will not be hurt when a blackſmith ſtrikes upon it with a large hammer, with all his ſtrength; but if he had an anvil only a pound weight upon his breaſt, the firſt ſtroke of the blackſmith would kill him. The *vis inertiæ* of the large anvil makes its reſiſtance equal to the ſtroke of the hammer, ſo that the anvil may be ſaid to ſtrike the hammer as forcibly as the hammer ſtrikes it; and hence the difficulty of putting large bodies in motion. Theſe are but ſmall inſtances of thoſe three laws of nature which Sir Iſaac Newton found univerſal, viz. *That matter is perfectly indifferent to either reſt or motion.* 2dly. *That bodies move in proportion to the force that acts on them.* And 3dly, *That action and re-action are equal, and contrary.*

4thly, *Matter attracts and is attracted*; *i. e.* all parts of terreſtrial matter have a tendency toward each other. A plumb-line on the ſide of a mountain is drawn out of its perpendicular by the attraction of the mountain. Two cork balls ſwimming on water, run together with an accelerated motion, and ſtick together. Water riſes above its level againſt the ſides of the bowl which holds it; and alſo in capillary or ſmall tubes: And hence the reaſon why water riſes in ſponge, ſand, between glaſs planes, &c. for all theſe may be conceived as made up of capillary tubes. Two planes of lead, marble, glaſs, iron, &c,

thruſt together, ſtick ſo cloſely, that exceſſive force alone can ſeparate them. 'Tis this *attraction of coheſion* that makes all bodies cohere, or maintain any diſtinct form; and as ſome parts of matter attract more forcibly than others, iron becomes heavier, and more compact, than wood; gold and platina have more particles in leſs room than any other metal; lead is different from ſtone, becauſe its particles attract one another more forcibly; ſo that all that variety which we ſee in both mineral, animal, and vegetable ſubſtances, ariſes from the different combinations of the elements of matter, the different degree of attraction in the particles of each, and in the different diſpoſition of the pores, or interſtices, that are between the particles of which they are compoſed. For the individual particles of the heavieſt and lighteſt bodies are all of the ſame weight, as may be proved by dropping a piece of gold, and a feather, down a tall glaſs that has no air in it to reſiſt their paſſage. Fire can deſtroy this coheſive quality in bodies, for a time, but makes no alteration in the original particles of bodies. It will inſinuate itſelf into gold, and ſeparate its particles, ſo as to make it into a fluid. Water and air are kept in a ſtate of fluidity by heat. Fire increaſes (perhaps cauſes) the repulſive qualities of all bodies. Metals ſwell with a ſmall degree of heat, as may be proved by the pyrometer. All nature is kept in motion by it; even blocks and ſtones ſwell by the heat of the day, and contract by the cold of the night. It gives water ſo repulſive a quality, that it flies off in ſteam. Air is ſo ſwelled by it, that to keep up its equilibrium, it is perpetually agitated by winds and ſtorms. Fire is the only *eſſential fluid*, and the cauſe of fluidity in other bodies, by ſeparating their parts. 'Tis ſaid, "where the ſphere of attraction ends, repulſion begins." The north pole of a magnet, at one-tenth of an inch from a ſuſpended needle, attracts it; but at five-tenths from it, it repels it. A glaſs tube rubbed with a dry hand, will alternately attract and repel feathers, leaf gold, and other light bodies. A ſmall needle will lie on the ſurface of water by its repulſion; flies run over it without wetting their feet, and a drop of oil will be ſuſtained by its repulſion, without ever touching the ſurface of the water. The rays of light are ſaid to be repelled from the ſurface of a looking-glaſs, &c. but fire, either in an active or latent ſtate, is the general cauſe of both repulſion and elaſticity.

5thly, *Elective attraction*, or the tendency which *one* part of matter has to unite with ſome other *particular* part in preference to every other part of matter, forms the grand baſis of Chemiſtry.—Thus, water ruſhes into union with ſpirit, but not with oil.——Acids have the ſtrongeſt affinity to fire and alkali.——Air attracts water with greater avidity than ſalt, ſo that freſh water is abſorbed by it from the ſurface of a ſalt ſea, &c. Of the elective kind of attraction alſo, is that of the magnet, becauſe it only attracts iron, ſteel, and itſelf; ſome hold magnetiſm and electricity as relations, becauſe ſteel ſtruck by lightening, or a ſtrong ſhock of electricity, acquires polarity and magnetic attraction. One Magnus, a ſhepherd, it is ſaid, firſt diſcovered this wonderful ſtone from its ſticking to the iron in his ſandals, and from him it had its name: Its attraction is at two oppoſite parts, called its poles, and if the ſtone was broken into a thouſand pieces, each piece would have its attracting pole: This attraction is ſtrongeſt in contact, and diminiſhes by a proportion not yet found out; but that point of a ſtone which attracts one end of a touched needle, will repel the other. Flavius Gio, of Naples, about 350 years ago, firſt diſcovered that a piece of ſteel rubbed on it, and then ſuſpended, had the property of pointing north and ſouth, and thence applied it to navigation. An hundred years after, it was found by Sebaſtian Cabot to have varied above 11 degrees eaſt. It continued to vary towards the eaſt at the rate of about one degree in ſeven years, till the needle formed an angle with the meridian of 30 degrees. It then returned toward the weſt at the ſame rate; ſo that about the year 1620 the line of *no variation* paſſed over England, the needle pointing then, directly north and ſouth. Since that time it has continued varying towards the weſt; and with us, at this time, the needle points 24 degrees weſt of the north. It is probable it will continue to vary weſtward, till it makes an angle with the meridian of 30 degrees (as it did at its eaſtern extremity); and then return weſtward, finiſhing its revolution in a period not yet well aſcertained. A line of no variation at preſent paſſes ſerpentine northward up the Atlantic Ocean, touching Brazil, and paſſes over the Bahama Iſlands, through South Carolina, Canada, over the Weſtern Lakes, and terminates at the north magnetical pole, ſituated about 30° from that of the earth, in the meridian of California. From thence the *line of no variation* proceeds over or near the earth's north pole, inclining eaſterly over Siberia, Tartary, China, the Ladrone Iſles, and New Holland, and then arrives at the ſouth magnetic pole, ſituated to the ſouth-eaſt of Van Diemen's Land, about lat 60° ſouth, and 150° eaſt long. from London. Theſe lines, as well as poles, move weſtward at preſent; and Captain Cook, in his laſt voyage, came ſo near to the ſouth magnetic pole, that his compaſs needle turned half round in 24 hours ſailing—and the dipping needle ſtood almoſt perpendicular. If a piece of ſteel, of ſpring temper, be balanced on a point horizontally, ſo ſoon as it has received magnetic virtue, it dips or inclines, ſo as to point in a chord towards the north or ſouth magnetic pole of the earth: But if equidiſtant from both, it continues horizontal, like a balanced bar. Moved from one end to the other of a long artificial magnet, it exhibits the ſame appearance.

The theory of making *artificial magnets* is derived from an *effluvium* ſuppoſed to flow from one pole of the magnet to the other,—the exiſtence of which is made very probable, by ſteel filings ſcattered over a plate of window glaſs, with a *bar magnet* under it, when the effluvium in its paſſage from one pole to the other influences the filings into many parallel and beautiful curves. If two pieces of ſteel, *ſpring temper*, made in ſhape of horſe-ſhoes, have their ends put together; and then two *bar magnets* juſt ſeparated, and of oppoſite poles, or an *horſe-ſhoe* or *natural* magnet be rubbed over them all the ſame way, *polarity* and *attraction* will be communicated to the ſteel; but if the two pieces be put together, ſo that the two repelling ends are joined, they attract ſtrongly: And hence ſeveral bars thus united form a very ſtrong magnet.—If a piece of iron, as a *conductor*, be put between the two poles, the magnet will long retain its virtue, particularly if it hang looſe ſo that it can turn itſelf north and ſouth.—Lay four ſmall bars of ſteel touching one another in a line, lengthwiſe; ſlide one pole of a magnet from the right hand to the left over them ſeveral times, and they will be good magnets: But if then you ſlide the ſame pole over them from the left hand to the right, the magnetic virtue will be entirely taken from them. *Fire* and *ruſt* deſtroy the power of theſe magnets, and time will weaken it, if a conductor of iron or ſteel do not form a magnetic circuit for the effluvium to paſs through. To recal the decreaſed virtue of a magnet, hang a large *ſand-bag* to the iron adhering to it, and keep every day increaſing the ſand. To give the virtue to a *knife*, draw it over either pole from hilt to point ſeveral times.

That the earth is magnetical is more than probable, from the vaſt quantity of ferruginous matter it contains; and becauſe the magnetic poles (though not oppoſite) affect a dipping needle in the ſame manner as an ordinary magnet. The dip in England is about 75° below the horizon; and all iron ſtanding with that inclination, or perpendicular, acquires magnetiſm; (probably by ſtanding in the direction of the earth's magnetic effluvium). A poker held *above* a ſmall compaſs (and inclining 75°) will attract by its knob the ſouth pole of the needle; but held *under* the compaſs with the ſame inclination, the knob will repel it. For the poles of the poker become changed by their change of poſition.

Fire is the moſt powerful agent in nature, and principally in the decompoſition of bodies. It is the only *eſſential fluid* in nature, and the cauſe of fluidity in other bodies, by ſeparating their parts; hence, even air itſelf may become ſolid when deprived of the fire it contains, as bodies of the moſt difficult fuſion become fluid when penetrated by a ſufficient quantity of the particles of fire. *All* bodies become hot by the approach of ignited bodies, and by friction; we find, however, that *light*, *heat*, and *electric fluid*, have ſo many qualities in common with *fire*, that hereafter it may probably be found they are all but modifications of the ſame principle. Rubbing, or friction, in *all* bodies produces *heat* and *electricity*; and both theſe dilate bodies, help vegetation, germination, evaporation, motion of the blood, the growth of the fœtus, and the hatching of eggs. Heat and electricity both reduce and melt metals; and bodies that receive *heat* with difficulty, receive *electricity* ſo, &c. May not the rays of the ſun be electricity in their emanation from the ſun; become light in our atmoſphere; and fire in the earth, by a chemical combination with the particles of the earth and air? All bodies have more or leſs affinity to fire; may not this diluted fire be abſorbed by various bodies, and lie in a concrete form in them, till called forth from them by friction or combuſtion? Experiments that favour this hypotheſis are theſe; 1ſt Rays collected in the focus of burning-glaſs, produce on opaque bodies the moſt intenſe heat that is producible by the art of man. 2d. Living vegetables imbibe light (as nutrition) from the air, and part with it back again into the air, in the act of combuſtion, boiling, or putrefaction; for rotten wood, putrid fiſh, the ignis fatuus; indeed all animal and vegetable ſubſtances, are luminous while decompounding by putrefaction(—which is but parting with the *inflammable principle* that was a conſtituent part of theſe bodies whilſt in health. 3d. Bodies in the act of *delivering* fire to the air, or any other affinitive menſtruum, are *univerſally hot*;——hence the heat of a common fire, inflamed gunpowder, &c.——The *heat* of efferveſcent mixtures, ſuch as diluted vitriolic acid and iron filings:——Copper and diluted nitrous acid:——Iron filings, water, and ſulphur, &c.

This principle (called caloric in the language of modern chemiſtry) is the grand antagoniſt of the attraction of coheſion. Theſe two oppoſing powers keep Nature in a ſtate of perpetual motion. When the attractive force is ſtrongeſt, the body continues in a ſtate of ſolidity; but if, on the contrary, heat has ſo far removed the particles of it, as to place them beyond the ſphere of attraction, they loſe their adheſion, and the body becomes fluid. Water when cooled below 32° of Fahrenheit's thermometer becomes ſolid, and is called ice. Above that temperature, its particles not being held together, it becomes liquid; but when raiſed to the height of 212° its particles give way to the repulſive power of fire, and fly off in vapour, and aſſume an aëriform ſtate: the ſame may be affirmed of all bodies in nature. But as no veſſels can contain this ſubtle fluid, as it eſcapes through every thing, it is difficult to define it, but by its effects; the preſſure of the atmoſphere checks it in part, and prevents fluids from flying off in ſteam, or gas, along with it. By ſurrounding bodies, and being interſperſed among the particles of bodies (according as thoſe particles are arranged or diſpoſed by that polarity which takes place when a body paſſes from the fluid to the ſolid ſtate), the body is ſaid to have a capacity for receiving, retaining, or parting with caloric, or fire. When this repulſion overcomes the adheſion of fluids, and the preſſure of the atmoſphere, the caloric flies off with the vapour, and the fluid is cooled; —hence, the cold produced by evaporations of all kinds. Ether, beer, &c. boil when in an exhauſted receiver, and ſink the thermometer. Spirit of wine boils in vacuo, by the heat of the hand, producing intenſe cold. Snow and ſea-ſalt mixt, attract heat from neighbouring or touching bodies, producing ice in a hot room; and by Glauber and ammoniacal ſalts, being mixt with ſpirit of nitre, quickſilver may be frozen into a hard metal. Hence we ſee why fire, going into a latent ſtate, produces cold; and into an active ſtate, heat; and why the blood (in an healthy ſtate) retains the ſame heat in cold and hot ſituations:

For evaporation cools both the earth and the human body.

From ſome things feeling colder than others, we find a difference in the conducting powers of bodies; for ſome convey the heat from the hand, and almoſt benumb it, as water, metals, &c. while others feel warm, as wool, cotton, &c. though when tried by the thermometer, they may be found all of the ſame temperature.

END OF THE FIRST LECTURE.

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LECTURE II.

Mechanics.

ALL matter, (except fire) is endowed with the power of attracting, and being attracted by other matter. The attraction of coheſion forms the ſmaller maſſes—but this power extended to a world, aſſumes the name of gravitation. This power unites the particles of the earth into a round and denſe ball, and holds every thing, animate and inanimate, faſt to its ſurface. That the whole earth is the attracting body, and not any thing placed in its centre, is clear, from finding that a plummet hung by the ſide of a precipice, is attracted out of its perpendicular by the precipice; and a body does not weigh ſo heavy 200 yards beneath, as on the ſurface of the earth. A body left to the power of this agent falls about a rod in the firſt ſecond of time; three rods in the ſecond ſecond; five in the third; ſeven in the fourth, &c. agreeable to the odd numbers, 1, 3, 5, 7, 9, 11, 13, &c. For the *vis inertiæ* of the falling body, added to the power of gravity in every ſucceeding ſecond, accelerates it, as the ſquares of the time. Thus, at the end of the fourth ſecond, the body has fallen about 16—at the end of the 6th ſecond, it has deſcended 36 rods, &c. This is proved by a projected ball falling from an horizontal line one inch in the ſame time in which it falls 3, 5, 7, &c. inches in the ſucceeding times; and by the ſuſpenſion of unequal weights over a pulley. Hence we find this power of gravity decreaſes as the ſquares of the diſtances increaſe (*i. e.* a ball, which weighs 9lb. on the earth's ſurface, would weigh only 1lb. at three ſemi-diameters of the earth above it). For it is found that the moon falls from a tangent to her orbit in this proportion; ſhewing that ſhe is actuated by the ſame law that makes a pebble deſcribe a curve when it is thrown from a ſling. For that pebble, if it were projected with proper force, and had a vacuum to move through, as the moon has, would go round the earth for ever as ſhe does.

Motion is rectilineal; *i. e.* all bodies put in motion by *one* force, endeavour to go off in a ſtraight line. Hence if a coach in ſwift motion be turned ſuddenly, it overſets by endeavouring to go off ſtraight: But if a body be impreſſed by *two* forces, in oblique directions, it will obey neither, but go the diagonal or medium of the ſquare. Hence a ball dropt from the maſt-head of a ſhip, under ſwift ſail, falls on the deck as if the ſhip was at anchor: And a ball ſhot horizontally from a tall tower, obeys neither the powder nor its own weight, but comes to the ground in a curve formed of the two. We ſhall in due time ſee that the planets move by this wonderful law.

The momentum of falling bodies is as the ſquare root of the height from whence they fall. If a body of any weight falls 1½ inch, it doubles its momentum; *i. e.* a pound let fall on a table 1½ inch, will ſtrike the table with a force equal to two pounds.—One hundred weight will ſtrike the ground with two hundred weight when let fall 1½ inch, &c.—Sink a cylindrical ſtick in a tall glaſs of water, and lay ſix ounces on its top, and it will ſink it to a certain depth; then let three ounces fall on the ſtick 1½ inch, and it will ſink it to the ſame depth. If it be let fall four times that height, it will have twice that effect, if nine times that height, three times the effect, &c.

Fluids ſpout by the ſame law. A pipe of the ſame bore as another, but four times as far below the ſurface of the water in a ciſtern, diſcharges twice as much as the upper one; if it be ſixteen times as far beneath the ſurface it will diſcharge four times as much as the upper one, &c. For the velocity with which a fluid ſpouts, at any depth below the ſurface, is equal to that which a body falling *that height* would acquire.

The *momentum* or force of a body, ariſes from its quantity of matter being multiplied into the velocity with which it moves: Thus if a *battering ram* be 1000lb. weight, and the velocity with which it ſtrikes a wall be 20, then is its *momentum* 20,000: But a cannon ball ſhall do the ſame execution, if its quantity of matter be no more than 10lb. provide it be thrown with a velocity equal to 2000, for 10 + 2000 = 20,000, ſo that the *momentum* of both are equal. This may eaſily be proved, by laying 2lb. weight upon a *ſpring*; if it throw it one yard, it will throw 1lb. two yards; and 8lb. will be counterpoiſed by 4lb. if it be hung on a balance at *twice* the diſtance from the fulcrum. Hence the force or power, of any machine, whether ſimple or compound, is eaſily computed; for when two bodies are ſuſpended upon any machine, ſo as to act againſt one another, if the perpendicular *aſcent* of one body be to the perpendicular *deſcent* of the other in the inverſe ratio of their weights, they will balance one another; and, therefore, ſo much quicker as the power moves than the weight, ſo much is the advantage gained by the machine, and gives this mechanical axiom, "That what is gained in power by any machine, is loſt in time of working it." Sir *Iſaac Newton.*

All kinds of mechanical engines conſiſt, more or leſs, of theſe *ſix powers*, viz. the *lever*, the *wheel* and *axle*, the *ſyſtem of pullies*, the *inclined plane*, the *wedge*, and the *ſcrew.*

The *lever* is a bar of wood, or metal, turning upon a prop or centre (commonly called the *fulcrum*), and is uſed either to raiſe weights or overcome reſiſtances. There are three kinds of levers, and in each of them, the velocity of each point is directly as its diſtance from the prop. When this *prop* is between the *weight* and the *power*, 'tis called a *lever of the firſt kind:* and ſo much as the power is further from the prop than the weight (or its centre of gravity), ſo much is the advantage gained by the power over the weight. *Iron crows*, *ſciſſars*, *pincers*, *rudders of ſhips*, *&c.* are *levers of the firſt kind.* *A lever of the ſecond kind*, is when the *weight*, or *reſiſtance*, is between the *prop* and the *power*, as in doors turning on hinges, knives that turn on the centre at the point; oars, *&c.* *A lever of the third kind*, is when the *power* is applied between the *weight* and the *prop*, as in rearing a ladder againſt a wall; moving our legs and arms by the power of the muſcles, &c. The *bended lever* differs in nothing from one of the *firſt kind*, but in form, it is like a hammer drawing a nail. In each of theſe levers, ſo much as the *power* moves farther, or ſhorter, than the weight, ſo is the advantage, or diſadvantage, of each. The power of a *compound lever* is found by multiplying the power of each into one another.

In the *wheel and axle*, the advantage of the *wheel* over the *axle*, is as their diameters; *i. e.* if the *wheel* be four times as large as the *axle*, a man may lift four times as much by it, as by his own ſtrength, allowing for friction. This *power* is the principal part of a common *crane*.

Upper pullies that are fixed, only ſerve to change the direction of the power, and give no mechanical advantage thereto; but the under block of pulleys, moving with the weight, give an advantage proportionate to the number of ropes by which the weight is ſuſtained; and which may be eſtimated alſo by ſo much as the power moves faſter than the weight. A *running pulley* doubles whatever advantage was gained by the other parts of a machine before it was applied, always allowing for friction, which in pullies is very great.

The *wedge* ſeparates heavy or cohering bodies, with a force proportioned, *as the thickneſs of its back is to the length*; *i. e.* if its back be one foot, and the length twelve feet, then may the momentum of the ſtroke which moves the wedge be one-twelfth only of the weight, or cohering force, of the parts to be ſeparated.

The *inclined plane* is half a wedge, and therefore its power is, *as its length is to its height*; *i. e.* I ſhall roll a cylinder up an inclined road of twenty yards in length and but one yard perpendicular height, with one-twentieth part of the force that would be neceſſary to lift it perpendicularly that yard.

The *ſcrew* may be conſidered as an inclined plane wrapt round a cylinder; therefore, as the power moves round the cylinder, while the weight riſes, the power has an advantage over the weight, as the length of one thread round the cylinder is to the diſtance of one thread from another; or as the velocity of the power is to the velocity of the weight.

In a *common jack* we have all theſe powers together, if to an arm of the fly the power be applied; and ſo far as that power moves farther than the weight, ſo much is the advantage which the power has over the weight.

If machines could be made to move without *friction*, the leaſt degree of power, added to that which balances the weight, would be ſufficient to raiſe it: But as the ſmootheſt bodies are full of pores, and little eminences, theſe will lock into one another in rubbing bodies, and greatly retard the motion of a machine. The friction in the *lever*, and in the *wheel* and *axle*, is very ſmall: In *pullies* it is very conſiderable: But in the *inclined plane*, the *wedge*, and the *ſcrew*, it is very great. The allowance made for friction in machines conſiſting of ſeveral of the mechanic powers, is uſually *one-third*; *i. e.* after calculating all the ſingle powers as above, and multiplying theſe into one another, from the laſt product I deduct one-third of it, and the remainder is the true momentum or force of the machine. Friction is of two kinds: The *rubbing friction*, and the *friction by contact*; the rubbing of the locked wheel of a coach againſt the road may repreſent the *firſt*; and the manner of its touching the road in its uſual motion, the *ſecond*. When the *firſt* kind of friction can be reduced to the *ſecond*, there is a manifeſt advantage given to the power of the machine, as is demonſtrated by the experiments with the friction wheels. Theſe wheels are hung ſo that their peripheries form an angle, in which the gudgeon of the heavy wheel turns. *Water wheels*, large *grinding ſtones*, and even *wheel carriages*, are hung in this way at a ſmall expence; but being apt to wear out very faſt, they are better fitted to ſmall weights moving with great velocity. And hence the friction balls in wheel carriages, cranes, &c. become ſoon uſeleſs. A *narrow* rubbing ſurface has much the advantage over a *broad* one, though they each ſuſtain the ſame weight, becauſe of fewer points and pores being in contact; hence the ſmaller the gudgeon or axle of a wheel the better, if it has but ſtrength to ſupport the weight. The friction in water that carries an under-ſhot mill, is much taken off by a ſloping pedal; the velocity of the float boards of the wheel ought to be one-third of the velocity of the water; the number of ſtaves in the trundle ought to be no even part of the number of cogs in the wheel that turns it; and the grinding-ſtone ſhould make about 60 revolutions in a minute.

Beſide the *mechanic powers*, and various inſtruments to explain *friction*, momentum, falling bodies, &c. the machines uſed to illuſtrate this lecture are, 1ſt. A moveable crane. 2d. A mill to ſaw marble. 3d. Ditto to ſaw timber. 4th. A common pile-driver. 5th. Voulou's pile-driver. 6th. The equable moving windmill, that cloaths, uncloaths, and turns itſelf to the wind. 7th. Drill-ploughs. 8th. Ventilators. 9th. Wheel carriages. 10th. Methods uſed in moving the great ſtone on which the ſtatue of Peter the Great is erected in Peterſburg. 11th. A compleat fortification. 12th. Boulton, Blakey, Smeaton's and the common fire or ſteam engines. 13th. Water engines of all denominations, viz. common pumps, forcing pumps, rope pumps, Archimedes's ſcrew pump; bucket engines, machines for draining, embanking, &c. &c. &c. Theſe, and many more, from their ſize, cannot be removed from the Winter Lecture-Room, now in *Conduit-Street*, *Hanover-Square*.

END OF THE SECOND LECTURE.

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LECTURE III.

Principles of Chemiſtry.

ALL bodies exiſting on the earth, may be arranged under three heads, viz. the *animal*, *vegetable*, and *mineral* kingdoms. The firſt comprehends all bodies endowed with life and ſelf-motion. The ſecond, thoſe which have life only, the power of growing, and propagating their ſpecies. The third, all bodies deſtitute of life and ſelf-motion. Bodies are alſo conſidered as *ſimple* or *compound*.—Simple bodies are ſuch as cannot be reſolved into any thing more ſimple, ſuch as pure earth, pure water, &c. Compound bodies conſiſt of two or more of the primary elements, ſuch as an *animal body*; for earthly particles and various fluids form its compoſition. That branch of philoſophy which examines the properties of theſe bodies, by compounding or decompounding them, is called CHEMISTRY,—a branch ſo extenſive and important, that the ſuſtenance of life—the arts and ſciences—various manufactories,—nay, even trade and commerce, depend upon a continual *compoſition* and *decompoſition* of natural bodies.

SOLUTION is a property of *fluids*, whereby they imbibe (or incorporate themſelves with) *ſolids*, by ſeparating their parts.—The ſea is a ſolution of ſalt in freſh water. Ink is a ſolution of vitriol and galls in water. Diluted nitrous acid diſſolves copper; when the ebullition is over, the liquor will be a ſolution of copper. Diluted vitriolic acid, in like manner, poured on iron, will produce a ſolution of iron. Quickſilver diſſolves lead, tin, &c. Gold diſſolved in aqua regia is a ſolution of gold, &c. and camphor, in like manner, is diſſolved in ſpirit of wine, &c.—Solutions

in water, ſpirits, acids, air, &c. are tranſparent; but mixtures are generally muddy or opaque.

DISTILLATION is the application of heat to ſeparate fluid and volatile parts from bodies; and to collect them in other veſſels by means of cold. Heat expands all bodies, and puts their particles into a repulſive ſtate; when this application becomes more powerful than the coheſion of the body, a decompoſition takes place. If ſea-water be put in a retort, and expoſed to the fire, the water ſoon riſes in the character of ſteam—this ſteam paſſing through a cold pipe, is condenſed, and brought back again into water, but freſh; and the ſalts being leſs volatile, remain in the bottom of the retort. Liquors that have gone through a ſtate of vinous fermentation, are diſpoſed to part with ſpirit—and ſpirit riſing in ſteam with leſs degree of heat than water, a ſeparation of the two is eaſily effected in a ſtill by tempering the fire,—hence the ſteam of the ſpirit paſſing through a long ſpiral pipe (immerſed in cold water, is condenſed:——when the ſpirit is all come over, the water begins to riſe in ſteam, and may be received in a ſeparate veſſel—the earthy and colouring particles of the wine will at laſt be found dry at the bottom of the ſtill.

SUBLIMATION is but a diſtillation of dry ſubſtances. *Sulphur* expoſed in a ſublimating veſſel, is melted with a very gentle heat, and riſes in ſteam, forming flour of ſulphur on the ſides and top of the veſſel, and is but the ſame ſulphur that was melted. *Gum Benzoin* melted within a tall receiver, with a ſprig of roſemary in it, riſes and forms an hoar-froſt appearance on the leaves of the roſemary.——*Phoſphorus* juſt covered with water, in a Florence flaſk expoſed over a lamp, ſublimes into the appearance of ſtars, and the aurora borealis. It riſes with the ſteam of the water, and ſtruggling to obtain the air, its menſtrum, forms beautiful coruſcations in the flaſk, particularly when ſeparated from the lamp, and expoſed in the dark.

PRECIPITATION is performed in fluid matters only—it is a diſuniting of two or more ingredients by the addition of another, which, by its greater affinity, unites with one of the ingredients, and ſeparates the others from it, and by which they generally fall to the bottom of the liquor. Copper diſſolved in diluted nitrous acid, is precipitated by iron—much of the diſſolved copper becomes revived by the phlogiſton or fire of the iron, and forms a ſkin of copper on the iron; the reſt falls to the bottom of the liquor, precipitated, &c. &c.

SATURATION ſignifies the point at which the attractive and diſſolving power of any menſtruum ſtops, when filled with the matter it is to diſſolve.—Solutions of ſalt or ſugar in water; of ſulphur in oil of turpentine; camphor in ſpirit of wine; ſilver in aqua fortis; water in air, &c. are tranſparent till fully ſaturated; if more be added, they ſink in their natural form to the bottom, undiſſolved, and the menſtruum is ſaid to be fully ſaturated. If water, ſpirits, oil, &c. be evaporated from the matter with which they are ſaturated, the matter aſſumes its natural form;—common ſalt will aſſume a cubical form; ſalt-petre the form of a priſm, &c. &c. adhering to the bottom and ſides of the containing veſſels.

AFFINITY. This term is of great extent in chemiſtry, and ſignifies *the tendency which the conſtituent parts of bodies have to unite readily with* SOME *ſubſtances in preference to others.* Water and vinegar have affinity, becauſe they are eaſily mixed together. Water and oil have no affinity, becauſe they will not mix, but ſhew a kind of repulſion to one another. If a mixture, A and B, have a third matter, C, added to them, to which A has a greater attraction or affinity than to B, then will A let go B, and join in union with C, and B is precipitated. Ex. 1ſt. Solution of ſublimate mixed with oil of tartar produces an orange coagulum; an acid (as the ſpirit of nitre) added, ſeizes the oil of tartar, as an alkali, to which it has a ſtrong affinity, the colour is diſcharged, and the liquor becomes pellucid. 2d. A ſolution of blue vitriol mixt with ſpirit of ſal-ammoniac, produces a blue-coloured alkaline liquor. The nitrous acid, added, ſeizes the ſal-ammoniac as an alkali, diſcharges the colour, and the liquor becomes pellucid; if then an alkali be made predominant (as oil of tartar) the fine blue is again reſtored. 3d. Acid ſolutions are detected by ſyrup of violets, which turns them red: but the ſame ſyrup turns an alkaline ſolution green. Hence red or blue flowers ſteeped in acid water, impart their colouring particles to the water, which becomes red: oil of tartar added, turns it green. 4th. Salts inſtantaneouſly cryſtallize when ſpirit of wine is added to their ſolution in water,—becauſe ſpirit and water have a greater affinity to one another than ſalt and water. 5th. Hydrogen gas, or inflammable air, is not inflammable of itſelf, any more than fixed air is effervescent; but it is a conſtituent part of a compound, which being let looſe, cauſes, by its mixture with the oxygen part of the atmoſphere, the phænomenon of inflammation. Hence phoſphorus when rubbed between the folds of brown paper to increaſe its ſurface, and give it a little warmth, takes fire ſo ſoon as it becomes opened out to the air. 6th. Two thirds of nitrous acid, and one third vitriolic acid mixed, and then poured on oil of turpentine, produce inſtant and tremendous inflammation! 7th. Ether dropt on water produces ice. 8th. Calces are revived, if while they are in fuſion, inflammable air be blown upon them. 9th. Equal quantities of regulus of cobalt diſſolved in diluted nitrous acid, and ſea-ſalt diſſolved in water, make an ink that comes and goes with heat and moiſture. 10th. Inviſible writing, with a ſolution of ſugar of lead, is rendered black by a ſolution of liver of ſulphur, each being diſſolved in water. This phlogiſtic effect will take place through a thick book, or even a ſtone wall. 11th Hemberg's pyrophorus requires one part ſugar and three parts allum, to be melted, ſtirred, and dried on an iron ſhovel till it becomes a blackiſh coal; then bruiſe it into powder, and put it into a long-necked bottle, and the bottle into a crucible filled with dry ſand: then place the crucible in a gradual fire, till the whole becomes red hot, and keep it ſo an hour, or till a weak ſulphurous flame has iſſued out of the bottle's neck a quarter of an hour; remove it by degrees, and cork up the bottle as ſoon as it will not burn it, or decant the pyrophorus into a dry bottle, well ſtopped from air. A little of this powder expoſed to moiſt air on brown paper, inſtantly takes fire. 12th. Sulphuric, or vitriolic acid contains more latent fire than water, and has a ſtrong affinity to water; therefore joining the water, its *latent fire* is let looſe, producing *ſenſible heat.* Hence iron pyrites lying in water produces heat, and becomes ink with an infuſion of galls; rain water running over quarries of ſuch pyrites above Bath, acquires the heat for which thoſe waters are celebrated. 13th. Vegetables contain much nitre; the water therefore in which potatoes, ſpinage, &c. are boiled, diſſolve the nitre, and hence brown paper ſoaked in ſuch water, becomes excellent *match* when cut in ſlips and dried. 14th. Silver diſſolved in diluted nitrous acid (or luna cornea) is precipitated by copper; for the acid has a greater affinity to copper than ſilver, therefore the ſilver precipitates, and forms thoſe beautiful ramifications called the arbor Dianæ.

ACIDS are both in a liquid and concrete form; have a ſour taſte, and efferveſce with alkalies. *Sulphuric* or *vitriolic acid* is fluid, tranſparent, colourleſs, and without ſmell like water, but much heavier: It is got generally from ſulphur, by diſtillation, or burning. *Nitric* or *nitrous acid* is of a brown colour, emits brown vapours, has a pungent ſmell, readily diſſolves moſt metals, and is extracted by diſtillation from nitre or ſalt-petre, moiſtened with vitriolic acid. It attacks the fire of metals, and has the greateſt affinity to it. *Marine acid* is extracted from common ſalt; it is of a yellow colour, and ſmells like ſaffron.

ALKALIES are ſaline bodies that combine readily with acids; in a concrete form they attract moiſture from the air, and become fluid; they have an acrid burning taſte; fuſe with a moderate heat; diſſolve earths with a ſtrong heat; become glaſs, &c. *Fixt mineral alkali* is obtained from ſea ſalt; *fixed vegetable alkali* from vegetables, both ſtanding a great heat without diſſipation. *Volatile alkali* is obtained from animal ſubſtances, by decompoſition and putrefaction, and flies off with a *ſmall* degree of heat; hartſhorn drops are of this kind. Alkaline ſalts combined with oils, form ſoap, &c.

SALTS are every thing with a ſharp taſte, and ſoluble in water. *Sea ſalt*, or *kitchen ſalt*, is a combination of marine acid and mineral alkali. *Luna cornea* is a ſalt formed by the union of ſilver and acid. *Verdigriſe*, ſalts formed by the ſolution of copper in vinegar. *Ammoniacal ſalts*, are an acid ſaturated with volatile alkali. *Sugar*, an eſſential ſalt, containing vegetable acid combined with earth and oil. *Potaſh*, a fixed vegetable alkali extracted from the aſhes of vegetables. *Nitrous ſalts* are found in old walls or places impregnated with animal and vegetable juices—they are neutral, and produce nitrous acid and fixt vegetable alkali.

METALS. *Perfect metals*, or thoſe that cannot be decompounded, are, gold, platina, and ſilver. *Imperfect metals*, are copper, iron, tin, and lead, which in fire or ſtrong menſtruums loſe their metalline properties, become an earth, or calx; but are revivable into their original metals by fire; or rather, according to the new principles of chemiſtry, the calces, or oxyds of metals imbibe oxygen air from the atmoſphere in the act of calcination, and thence become oxyds. Theſe oxyds are revived by their oxygen combining with the charcoal of the fatty, or inflammable ſubſtances heated with them, by which carbonic acid gas (or fixt air) is formed. The metal being thus left free, recovers its metallic or reguline form. Pure metals are always found in their metallic form. *Gold* is unalterable by art, is one of the heavieſt of all known bodies (except platina), expands ſo much, that a grain may be beat into a leaf of fifty ſquare inches, and a gold wire one tenth of an inch in diameter, will ſuſpend or ſupport 500lb. weight without breaking. Reduced into fine powder, it is eaſily attacked by acids, but its metallic nature is in no reſpect altered. Gold diſſolved by aqua regia, and then precipitated by volatile alkali, and waſhed and ſuffered to dry, explodes by a ſmall degree of heat, with a quickneſs and violence far exceeding gunpowder. Ether poured on a ſolution of gold in aqua regia, and the mixture ſhook, the gold will leave the aqua regia and paſs into the ether.—Gold will continue months in a hot fire without loſing any weight. *Platina.* This metal is found in ſmall, angular, ſhining grains in the gold mines of South America; it is nearly as heavy as gold naturally, but deprived of the iron with which it is generally united, it is heavier. It diſſolves in aqua regia; but bids defiance to ſimple acids, or any fire, except that of a large burning glaſs. *Silver* is the third unalterable metal—it fuſes in a ſmall heat; is nearly as ductile as gold; a wire of it, one-tenth of an inch diameter, will ſuſtain 270lb. It aſſumes a black appearance when expoſed to phlogiſtic vapours, for it is capable of over ſaturating itſelf with the inflammable principle. Nitrous acid diſſolves ſilver more completely than any other acid. *Copper*, though an imperfect metal, comes near to ſilver in point of ductility.—A wire, as above, ſupports 299lb. Moiſt air tarniſhes, and even calcines it; this ruſt, or calx, is verdigriſe. Acids, alkalies, ſaline matters, and oils, more or leſs diſſolve copper, and the ſolution is of a green colour, and poiſonous; hence culinary veſſels of copper ſhould be kept well tinned. A ſolution of copper in volatile alkali is blue when expoſed to the air, but loſes the colour when corked up; opened, it again becomes blue, &c.——So water impregnated with too little copper to be diſcovered, turns blue with a few drops of volatile alkali. Copper is moſtly found combined with ſulphur in mines; and is eaſily ſeparated from other metals by ſulphur. It requires a ſtrong heat to melt it, emits pernicious fumes, and burns with a green or blue flame. It eaſily combines with other metallic ſubſtances—with zink it becomes *braſs*—with tin, *bronze*, or *bell-metal*, &c. *Iron* is the moſt uſeful, the hardeſt, moſt elaſtic, and, except tin, the lighteſt, of all metals. Such a wire as above, ſupports 450lb. As an ore, or a calx, it is not attracted by the magnet; but when metallized by roaſting in the fire, it is attracted. In water, moiſt air, acids, fire, &c. it becomes ruſt, or *crocus martis.* Iron joined by fatty ſubſtances in a ſtrong fire, without the free acceſs of air, becomes *ſteel*; and ſteel made red hot, and ſuddenly cooled in water or oil, becomes ſo hard tempered, and brittle, that edge tools, files, &c. are made of it. In the act of heating, it changes colour, and hence many ſteel ornaments are made blue. Iron has great affinity with ſulphur, and its fuſion is ſo much facilitated by it, that if iron in white heat be rubbed with ſulphur, it falls in liquid drops united with the ſulphur; and if 60 lb. of iron filings and ſulphur, made into a paſte with water, be buried a few inches under ground, it will ſwell, grow hot, emit vapours and flame, and ſhake the ground about it like an earthquake. Iron may be allayed with any metal except quickſilver and lead. *Tin* is the lighteſt, leaſt elaſtic, or ſonorous, of any metal. A wire as above, ſupports 50lb. All acids diſſolve and deprive it of its metalline form. It melts with leſs heat than will make it red hot, and calcines in a grey powder, called putty, (uſed in poliſhing metals, glaſs, &c.) It allays with all metals, gives them brittleneſs; and its vapours impair the ductility of all metals. It amalgamates with quickſilver, and is then uſed to cover looking glaſſes; compounded with lead, it forms the ſolder of the plumbers. —*Lead* is ſtill ſofter than tin; a wire as above only ſuſtains 29lb.—Acids diſſolve it, the vitriolic very ſlowly—fumes of vinegar ruſts it into *white lead*. Calx of lead is made into wafers; boiled in linſeed oil, it becomes the drying oil of the painters. Lead kept in a ſtate of fuſion, with a current of air paſſing over it, imbibes the vital part of the air, and becomes calcined, and is then called *red lead:* a ſtronger heat vitrifies this calx into *litharge*; and a ſtill ſtronger heat, into *glaſs of lead*, which will run through the crucible like water through a ſieve. This glaſs facilitates the calcination of imperfect metals, and is therefore uſed to purify the *perfect* metals. *Mercury*, or *quickſilver*, is like fluid ſilver, opaque, and very heavy. By great cold it can be made ſolid, and malleable as lead. It riſes in vapours by a ſmall degree of heat, and when theſe vapours are collected, they are found the very ſame as quickſilver. Hence it is eaſily diſtilled, and by that means eaſily ſeparated from lead, tin, &c. Acids and alkalies combine with mercury. Vapours of mercury and marine acid meeting, form cryſtals like flattened needles, called *corroſive ſublimate.* Mercury ſhook in vinegar, exhibits a curious phænomenon; and it is luminous when ſhook in vacuo. Quickſilver triturated with ſulphur, forms *Ethiops mineral*; and this frequently ſublimated, becomes cinnabar— or the vermillion of the painters. Cinnabar is alſo found a native in the mines, and may be conſidered as the ore of quickſilver.

EARTHS.

Earths make up the ſolid part of our globe; they are ſo intermixed, that it is difficult to come at their components, which are, 1ſt. *Calcareous earths, i. e.* lime-ſtone, chalk, ſtalactites, or ſtone icicles, marbles, or any earths that effervеſce with acids; that fall in white powder when burnt; that will not melt into glaſs by heat; but will melt when mixed with borax, or calces, and aſſiſt the fuſion of lead, copper, and iron. *Siliceous earths*, or precious ſtones, as the diamond, ruby, topaz, opal, agate, cornelian, flint, jaſper. Many of theſe ſtrike fire with, and even ſcratch ſteel;—do not melt with the ſtrongeſt fire; and do not effervеſce with acids. *Argillaceous earths*, or clays that harden in the fire, and uſed to make porcelain; and clay marles, that moulder in water, and effervеſce with acids, uſed as manure. *Micaceous earths* are compoſed of thin leaves, or lamina, with ſhining ſurfaces, and which divide into thinner leaves in the fire, and become brittle. *Aſbeſtus earths:* Theſe do not alter in the fire; are flexible and ſtringy, capable of being ſpun into threads, or wove into cloth. *Zeolites* are harder than calcareous ſtones; melt eaſily in the fire with ſwelling and ebullition; and diſſolve with acids without effervеſcence.

END OF THE THIRD LECTURE.

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LECTURE IV.

Pneumatics, or Mechanical Properties of Air.

THE air is a thin fluid, which encompaſſes the globe of the earth on all ſides, revolves along with it round its axis, and attends it on its annual journey round the ſun. If a peach be ſuppoſed to repreſent the earth, the air will be aptly ſignified by the down growing on its ſurface, covering it on all ſides like an Ocean.

This body of air, (together with the clouds and vapours that float in it) is called the atmoſphere; and it reaches about forty-five miles above the ground before it degenerates into too thin an æther to refract the rays of light, or for any creature to breathe; this is known by meaſuring with a barometer the weight of the atmoſphere in a low valley, and on a mountain, and may be familiarized by ſuppoſing a thouſand fleeces of wool one piled upon another, where the loweſt will be greatly compreſſed or ſqueezed together, the next not ſo much, the next not ſo much as that, &c. till we come to the uppermoſt, which will lie in its natural looſe ſtate. The air, by being elaſtic, and partaking of the earth's attraction, is neceſſarily drawn into a progreſſive ſtate like this, and is ſaid to conſiſt of two principles, *viz.* $\frac{1}{3}$ oxygen or vital air, and $\frac{2}{3}$ azote, or air unfit to ſupport flame, or animal life.

The air is ſo ſubtil that it pervades the pores of all bodies, and enters into the compoſition of moſt animal and vegetable ſubſtances; yet it is a body, becauſe it excludes all other bodies from the place it poſſeſſes, if ſo confined that it cannot eſcape; hence the origin of the diver's bell, for if we ſink a bell in water with the mouth open downwards, little water will make its way into it, and a perſon may deſcend and live at a conſiderable depth, if a veſſel of the ſame kind be kept conſtantly ſupplying him with freſh air, and *that* made noxious by his breathing be let out by a pipe reaching from the upper part of the bell above the ſurface of the water. A forcing-pump on board the ſhip from whence the bell is lowered ſometimes ſupplies freſh air through a flexible pipe, to the diver: For air undergoes a decompoſition in the lungs, and the ſame air cannot be breathed over and over again, becauſe the vital part of it is abſorbed by the blood, and the azotic part uniting with a carbonic principle (fixt air) from the venal blood, is thrown out from the lungs unfit for ſecond inſpiration. This is proved by taking a ſmall quantity of air ſeveral times into the lungs, when a candle will not burn in it, and a bird ſoon dies in it. A living plant cures this air, by abſorbing the carbonic principle; (the great baſis of vegetable nutrition.) The plant becomes nouriſhed by the ſame proceſs by which the air is cured; thus do the animal and vegetable kingdoms mutually work for each other; and a vegetable in an inverted glaſs of water (expoſed to light) will return the air *pure*. The blood is protruded from the heart to the extremities through the arteries; and from thence returns through the veins to the heart, where it takes up the new blood formed from the ſtomach, and with it makes a digreſſion to the lungs in a thick and dark coloured ſtate; here it receives *vital air*, and becomes thin and florid by it; returning into the circulation fit to flow through the fineſt ramifications! But when air has loſt its oxygen, the blood returns into the circulation, a thick ſemifluid, and filling the finer veſſels, forms ſuch preſſure upon the neighbouring nerves, as ſoon produces ſpaſms, convulſions, and death. Thus died the people in the hole at Calcutta; and ſo would any land animal die ſhut up in a ſmall and cloſe place. Hence we ſee the neceſſity of breathing this pabulum as pure and open as poſſible. In this decompoſition, the latent fire of the atmoſphere is let looſe in the lungs, which, together with thoſe that form the decompoſition of our food, forms *animal heat.*

The air has all the properties by which a fluid is diſtinguiſhed; it yields to the ſlighteſt impreſſion, its parts move eaſily among one another, and animals breathe and move through it without any difficulty. It can be compreſſed into a leſs ſpace than it naturally poſſeſſes. It can occupy a greater ſpace than it naturally poſſeſſes. It is of different denſity in every part upward.

As the air is a body, it needs muſt have *weight*; this is proved, 1. By its preſſing the hand that covers the top of an exhauſted receiver. 2. By immerſing the ſtem of a bolt-head into a veſſel of water, and covering both with a receiver, then exhauſting the air out of both; on letting in the air on the ſurface of the water, it forces it into the exhauſted bolt-head. 3. A bottle that holds a wine quart being emptied of air, and weighed, is found to be about 17 grains lighter than when it is full of air; ſo that a quart of air on the earth's ſurface is 17 grains. 4. If a wet bladder be tied over the top of an open receiver, then ſet to dry, and, after this, the air be exhauſted from under it, the air's weight will burſt the bladder with a ſurprizing report. 5. On a moveable plate place a tall receiver, open its cock, and exhauſt the air out of it; then ſhut the cock, and immerſe the ſtem in which it is fixed into a veſſel full of water; on opening the cock, the air's preſſure on the water will force it into the receiver in a beautiful fountain. 6. If a hole be made in the bottom of a cup, and have a bit of dry hazel or willow branch fixed into it, and this be put into a hole on the top of a receiver: when quickſilver is poured into it, and the air exhauſted, the quickſilver will be forced through the pores of the branch by the weight of the incumbent air, and will fall in a curious ſhower into the receiver. 7. If a tube of 32 inches long, and open only at one end, be filled with quickſilver, and then the open end immerſed in a jar of quickſilver, *that* in the tube will ſink to the height the quickſilver ſtands in the barometer; if this jar and tube be put under a tall receiver, and the air exhauſted, the quickſilver will deſcend out of the tube into the jar; but upon admitting the air again into the receiver, its preſſure will drive up the quickſilver into the tube, and ſupport it therein as it ſtands in the barometer; which proves that the quickſilver in the barometer is kept up ſolely by the weight of the air. 8. If the air be exhauſted out of two braſs hemiſpheres of about 12 inches area, it will require a force equal to 180 pounds to ſeparate them.

To prove that theſe effects are not produced by *ſuction*, and that there is *no ſuch principle in nature:* 1. Place a ſmall receiver at ſome diſtance from the hole in the pump-plate, and cover it with a large one *over* the hole; on exhauſting the air, the ſmall one will remain looſe, while the large one is made faſt to the plate; but on letting in the air, the big receiver will be releaſed, and the ſmall one preſſed down. 2. If a pump be placed in water under a receiver, and the air exhauſted, no water can be made to raiſe in the pump. 3. If two moveable plates be fixed upon a pump-plate, with communications between them that can be ſtopped by cocks, if the air is exhauſted out of a receiver placed on one of them, and then a receiver be placed on the other, and the communication opened, half the air in the laſt will, by its ſpring, make its way into the firſt receiver, and both ſhall be fixed on the plates.

Breathing is in ſome meaſure performed by the power of the intercoſtal muſcles acting upon the ribs; they are diſpoſed in form of a ſemicircular arch, and articulated with the vertebræ behind, and connected with the ſternum before, which are the two centres on which they move: The diaphragm is a partition drawn acroſs the body, dividing the thorax, or cheſt, from the abdomen, or belly; it is a muſcle, and by its diſpoſition and ſtructure capable of expanſion, whereby it becomes concave downward, and of contraction, whereby it becomes flat; and by this motion alternately increaſing and diminiſhing the cavity of the thorax, and of courſe condenſing and rarefying the air in the lungs, produces the action of breathing. This is repreſented by the lungs-bladder, whoſe inſide has a communication with the external air, though it is encloſed in a thorax of glaſs with its bottom cloſed by a bladder, tied flaccid, repreſenting the diaphragma.

The *elaſtic quality*, or *ſpring*, of the air, is thus proved, 1. If an almoſt empty and tied bladder be put under a receiver, and the air exhauſted, the ſpring of the air in the bladder will then ſhew itſelf by ſwelling up the bladder, as if it was blown. 2. If a little of the ſhell be cut off from the ſmall end of an egg, and the egg put under a receiver, on exhauſting, the bubble of air in the big end of the egg will expand itſelf, and drive out the contents of the egg. 3. If a fiſh in water be put under a receiver, and the air exhauſted, its air-bladder will ſwell the fiſh ſo as to make it ſpecifically lighter than water, and of courſe the fiſh will be buoyed up to the ſurface. 4. If a cubic inch of dry wood in warm water be put under the receiver, and the air exhauſted, large and innumerable bubbles of air will come out of the wood and make the water ſeem to boil; and in this manner may air be drawn viſibly out of the hardeſt bodies. 5. A withered apple in an exhauſted receiver will be plumped up, and look quite freſh, by the ſpring of the air in the inſide of it; and if a freſh one be pricked all over with a bodkin, and put in water under a receiver, on exhauſting, it will appear as if it was roaſting by a fire. 6. If a tall receiver be exhauſted, and the neck of the veſſel joined to its bottom be half full of water, the ſpring of the air on the ſurface of that water will force it out into the receiver in a beautiful fountain. 7. If a little air be tied up in a bladder, and put in a convenient veſſel with great weights upon it, on exhauſting the air, the ſpring of the air in the bladder will lift the weights, and ſhew that its ſpring is equally forcible with its preſſure; therefore, though a middle-ſized man ſuſtains above 30,000lb. weight on his perſon, yet the equal ſpring of air within him makes him inſenſible of it.

That the air may be condenſed or ſqueezed into leſs room than it naturally poſſeſſes is proved, 1. By putting a blown bladder in a receiver; if a forcing ſyringe be then applied to the receiver, and a quantity of air forced into it, the bladder will be ſhrivelled up by the ſuperior preſſure of the condenſed air. 2. If a copper ball be half filled with water, and a quantity of air forced into it as above, through a ſpouting pipe that reaches nearly to the bottom of the water, the ſpring of the condenſed air on the ſurface of the water will exhibit an amazing fountain. 3. The moſt formidable inſtance of condenſation is in the magazine and walking-cane wind-guns; where the condenſed air has a ſpring capable of diſcharging 20 or 30 balls with one charge, one after another, with the ſame force as if charged with gun-powder. Air ſo ſqueezed has a portion of its latent heat forced out, and the containing veſſel becomes hot, like hammered iron.

Heat and cold, or, if you will, the preſence or the abſence of fire, are the uſual cauſes of the air's rarefaction and condenſation: If *air* be heated, it ſwells, ſo that the ſpace it poſſeſſed before it was heated, will contain fewer particles than it did in its cold ſtate. *Wind* muſt be the neceſſary conſequence of this; for by what means ſoever the equilibrium of the air is deſtroyed, its neighbouring parts will never be at reſt till the balance is reſtored: Hence the reaſon why air ruſhes ſo violently into a glaſs-houſe; into a cloſe room with a great fire in it; into warm towns, &c. When the ſun's heat is increaſed by the reflection of ſands, or the ſides of rocky mountains, &c. the air will be rarefied, and by the ruſhing in of the colder neighbouring air will be forced up into the higher part of the atmoſphere, as light ſmoke is up a chimney by the heavier air. If a large cloud keep the ſun's rays from the *air* under it, but rarefies *that* all round it, a wind will ruſh from beneath the cloud in all directions.

Upon this principle alſo, we account for the *trade winds* which conſtantly blow from the eaſt toward the weſt about the equator; for, as the ſun paſſes over the earth in that direction, and rarefies the air as he goes, by heating the earth, and bottom of the ſea (for tranſparent bodies receive no heat from ſolar light), the colder air will ruſh after him. The effect is alſo increaſed by the greater centrifugal motion, which the equatorial parts of the globe have than thoſe parts nearer the poles; by which the globe ſlides, as it were, from under the air, cauſing an apparent motion in it the contrary way to that on which the earth turns on its axis——Hence alſo the *monſoons*; the *day* and *night* breeze on the iſlands in the Weſt-Indies; the wind from weſt to eaſt on the coaſt of Guinea; and the currents of Florida, Gibraltar, &c.

That *water* is preſent in *air*, is evident from ſeeing it precipitate in a cloud as a receiver is exhauſting on the air-pump; from the *dew* on windows, or other cold bodies when water ſtands for ſome time in a hot room; from the wet hair of thoſe who aſcend the ſides of mountains; and from its entering ſponges and hydrometrical inſtruments when hung in air: from many proofs, it is evident that *air is a menſtruum for water*. A cubic foot of atmoſpheric air is capable of holding 12 grains of water in ſolution. *Air*, lying on *water*, and rubbing perpetually againſt it, from this contact, and their natural attraction, the two fluids mutually imbibe one another; (for air may be ſeen in water placed in an exhauſted receiver). That an *heavy* body can riſe in a lighter one, when its particles are ſeparated, and its ſurface by that means is increaſed, is certain from *leaf-gold* floating in air; being diſſolved, and of courſe hanging in *aqua regia*; *copper* in *aqua fortis*, &c. *Water* riſes in *air* by the ſame law; and the ferment occaſioned by all ſolutions, may be ſeen in the air along the ſurface of wet ground, on a warm day, in that *quivering* which the rays of the ſun ſuffer in paſſing through air and water not yet *intimately united*. *Heat aſſiſts all ſolutions*; hence the quantity of clouds and rain where the ſun is vertical:—The drying quality of the air in ſpring, and the rains and fogs in winter; for ſummer's warmth aſſiſts in filling the air with water, and winter's cold condenſes and brings it down in high latitudes; and as the higher regions of the air are cold, and thin, little aſſemblages of particles are diſperſed through the air and form *clouds*, about the height of the mountains:—The winds, and their own attraction, aſſiſt this junction till they become big enough to precipitate in a *drop of rain:* If the drop be frozen in its deſcent, it falls on the ground an *hail-ſtone:* If the *cloud* be frozen, then broken fragments of it deſcend in *flakes of ſnow. Fogs in an evening* are occaſioned by the cold condenſing the vapours newly raiſed from the ground, before they are thus chemically united with the air.

'Tis unneceſſary to point out here, how admirably theſe properties coincide with the general ſcheme of the creation.

END OF THE FOURTH LECTURE.

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LECTURE V.

Pneumatics, or Chemical Properties of Air.

SOUND is cauſed by any thing that gives a ſmart ſtroke or a tremulous motion to the air; waves thus occaſioned, ſtriking upon the outward ſhell of the ear, are from thence conveyed up the auditory tube, and ſtriking againſt the tympanum, or drum, are ſo increaſed, that in making their way up the labyrinth, they give a ſhock to the auditory nerves, and, by their means, is conveyed to the ſoul the idea of ſound. The artificial ear makes this very evident. And the clock ſtriking in vacuo without being heard, is a proof of air being a conductor of ſound. Muſical ſtrings, in tenſion, ſtruck by a bow, a finger, the wind, &c. will divide themſelves into imaginary frets, or bridges, viz. into halfs, thirds, fourths, &c. A bridge, either real or imaginary, dividing a ſtring into *two* equal lengths, each (*vibrating according to their weight*) will be an *octave* to the whole ſtring, as half will vibrate twice as faſt as the whole; and hence every ſecond wave unites with the firſt of the whole ſtring, and gives a pleaſing ſenſation to the ear. If a ſtring be divided into *three equal parts*, each will vibrate three times while the whole ſtring vibrates once; hence every third wave coming in contact produces a pleaſing ſenſation, and the chord is called a *Twelfth*. Two thirds of this ſtring vibrate *three times* while the whole ſtring vibrates *twice*, and gives that ſweet chord called a *Fifth*. *Seven-ninths* of a ſtring produce the major *Third*; and *Three-Fourths*, the *Fourth*. Hence, waves claſhing againſt one another without contact, produce *diſcords* in muſic, and ſerve as foils or reliefs to the counterpoint of according waves. Hence alſo the mechanical ſympathy of muſical inſtruments tuned in uniſon; one of which will ſound when the other does, by the waves it produces. An harpſichord replies to every word ſpoken in the room where it ſtands, when its ſtrings have no dampers upon them. Particular notes in an organ will ſhake the wainſcot, ſet dogs a howling. Hence all the various ſounds produced by the Eolian harp, when tuned in uniſon, and expoſed to a current of wind—the ſtrings divide themſelves into imaginary bridges, and produce *octaves*, *fifths*, *thirds*, *twelfths*, *fifteenths*, &c. The maſterly performer on the violin aſſiſts this propenſity, by touching lightly thoſe aliquot parts of a ſtring where nature would make this imaginary bridge, and hence are produced thoſe notes called *harmonics*.

Any thing elaſtic will conduct ſound, as well as air, and even better; if an ear be put to one end of a long beam, and a ſmall ſcratch be made at the other, the ear will diſtinctly hear it. Echo, is a reflection of the air-waves, from hills, rocks, &c. as light is reflected from a mirror. Sound travels 1140 feet in a ſecond of time, and returns by echo with the ſame velocity—hence the impinging waves againſt the aliquot parts of the arch of St. Paul's dome unite ſo nearly at the ſame time, on the oppoſite point to the ſounding body, that whiſper is heard as if the mouth and ear were cloſe together. Air-waves (naturally flying off globularly), are directed by the ſpeaking-trumpet into a ſtraight line; and thus condenſed, they fly farther through the air, and make a proportional impreſſion on the ear. The trumpet's mouth being opened in the logarithmic curve, reverberates the ſtruggling waves into a line with the axis of the inſtrument; ſo when two of them are placed in a line, with their mouths placed towards each other, the ſmalleſt whiſper in one will be heard many yards by an ear placed at the other. Hence they are alſo uſed to aſſiſt imperfect hearing.

Marine acid air, is a gas, the acid of ſea ſalt, diſengaged from ſea ſalt by the ſulphuric acid. On their mixture a briſk effervefcence takes place, which through quickſilver, produces an acid that will be inſtantly abſorbed by water. When this acid is ſtrongly oxygenated, it diſſolves the gummy, oleaginous matter of raw linen or cotton, and is

now

now applied to bleach theſe cloths with ſucceſs. Manganeſe and marine acid are put in a glaſs retort over a common fire; the gas ſo produced will bleach any linen or cotton expoſed to it, and diſcharge colours; but if the gas is paſſed into the water, in tall inverted tubes, the water will alſo bleach thoſe fabricks in a ſhort ſpace of time; this is called the *oxygenated muriatic acid.*

When the atmoſphere is light, the noxious air pent up in the cavities of mines (communicating with the outward air) will, by its effort to reſtore an equilibrium, ſwell into the mine, and hence the ſuffocating damp which is met with in mines when the barometer is low. This damp is made on the air-pump by letting air into an exhauſted receiver, through the flame of charcoal, ſulphur, flame of a candle, &c. into which, if an animal be put, it ſuffers inſtant death. The fire-damp proceeds from the ſame cauſe, only its particles are of an inflammable nature, as ariſing from the ſulphurous, nitrous, or oleaginous ſtrata in the mine: This, taking fire by the lights uſed by the workmen, will run like a train of gunpowder through the works; and as it is confined, the elaſticity occaſioned by the heat, will cauſe ſuch exploſions as frequently blow up the mine. This damp is made on the pump by letting the air into an exhauſted receiver through the flame of the oil of turpentine, or other inflammable matter; after which, if a lighted candle be put in the vapour, it will take fire.

As the pores and cavities of all bodies are filled with air, an animal put under a receiver, and the air exhauſted, will ſoon die; becauſe as the air is drawn out of the lungs, *that* in the body will expand and ſwell the animal, ſhrivel up its lungs, and thereby ſtop the circulation of the blood.

Carbonic air, the aerial acid, or fixed air *(that wonderous antiſeptic)*, ariſes from the effer veſcence of many acid and alkaline mixtures, and eaſieſt from chalk and diluted oil of vitriol.—Liquors fermenting diſcharge plenty of it, and it is found alſo in the common atmoſphere. It is a conſtituent part of chalk, marble, lime-ſtone, and all calcareous earth. Water imbibes it, and thence acquires the ſparkling appearance, acidulous taſte, and medical qualities of *Pyrmont-Water*. Though noxious when breathed, it cures the ſea ſcurvy, putrid inteſtines, inflamed or putrid ſores, &c. when let looſe in the ſtomach from malt, ſugar, ſaline draught, ſour crout, and other vegetables.—It is heavier than common air, ſo lies at the bottom of the Grotto del Cano, and other lime-ſtone caverns. It is now ſaid to be the reſult of combining charcoal with oxygen.

Nitrous air is commonly produced from effervefcence of copper filings and the nitrous acid. It diminiſhes common air, in proportion to its purity; and their mixture produces a brown effervefcence.—This gas is compoſed nearly of two parts, by weight, of oxygen, combined with one of azote, and is not miſcible with water. This azote having ſo great an affinity to oxygen, and in this ſtate being far from ſaturation, it will ſo attract it even from the atmoſphere as to diminſh all airs in proportion to the oxygen they contain.

Hydrogen gas, or *inflammable air*, is eaſieſt procured from iron filings and diluted vitriolic acid; the acid ſeizes the earth of iron, and lets looſe its fixed fire, exhibiting it as *elaſtic air*. This *gas* is imbibed by any metallic calx, in a ſtrong heat, and the calx, becomes revived into its original metal. Lead in calcining, loſes its inflammable principle—and becomes a calx called minium or red lead: But if the calx be placed in inflammable air, and the focus of a burning lens heat the calx it inſtantly begins to imbibe the inflammable air, ſwallows it up, and ſoon becomes the individual lead it was before the proceſs. This is taking a metal in pieces and putting it together again; and intimates the *inflammable principle to be the ſame in all bodies*, viz. that inflammation in coals, candles, wood, &c. ariſes from letting looſe latent fire from theſe ſubſtances into the air. The new doctrine would prove that hydrogen gas, or inflammable air, is produced from water. For if 274 grains of ſoft iron, in thin plates, be made red hot in a tube, with the ſteam of water forced through it, the product will be 416 cubical inches or 15 grains in weight of inflammable gas (13 times lighter than atmoſpheric air), and the water will be found to have loſt in ſteam 100 grains, the iron in the tube will have acquired 85 grains of additional weight and become a mere oxyd; ſo that theſe 85 grains added to the 15 grains of inflammable air will give the 100 parts of water loſt. And if equal quantities of inflammable or hydrogen gas, be burnt with oxygen gas in a cloſe veſſel, the product will be *water*, of the ſame weight with the two ignited airs. But how air, 13 times lighter than common air, can be thus accurately weighed, ſurpaſſes my comprehenſion! This *inflammable air* being ſo much lighter than common air, riſes from bogs, and putrefying ſubſtances, into the higher regions of the atmoſphere, and lodging there, frequently receives inflammation from lightning or electricity, giving *Thunder* its long progreſſive ſound—— *Lightning* the property of ſpreading over the whole hemiſphere——and, when by winds it is drawn into long ſtreaks acroſs the hemiſphere, and ignites at one end, the inflammation runs acroſs the hemiſphere, and we call the phœnomenon *falling ſtars*, *fiery dragons*, *meteors*, *will-o-th'-wiſps*, &c.—A ſoap bubble, filled with inflammable air, riſes in the atmoſphere like a cork in water, and is an air-balloon in miniature, riſing from its ſpecific levity; ſuch a balloon was made by the Lecturer twelve years before any appeared in France. *Inflammable air*, when mixt with an equal quantity of common air, or a third of vital air, explodes when confined in a gun, and inflamed by electricity, ſo as to diſcharge a ball with a force nearly equal to gunpowder.

Copper and ſpirit of ſalt produce an air through quickſilver) that is very noxious,—quickly abſorbed by water, and in which a candle burns green. Water ſaturated with it, is a ſtrong ſpirit of ſalt, and diſſolves iron with great rapidity.

Alkaline air is expelled by a candle from a glaſs retort filled with one-fourth pounded ſal-ammoniac, and three-fourths quick lime mixed.

Vitriolic acid air is produced by oil of vitriol juſt covered with olive oil in a phial, and diſcharged by a candle through quickſilver. Ice inſtantly melts ~~in this~~ air; and alkaline air put to it produces a white flakey precipitation.

Fluor acid gas, is forced from Derbyſhire-ſpar by heat; the ſpar is pounded, and mixed with ſulphuric acid, the water ſeizes the acid of vitriol or ſulphur, and the acid of the ſpar attacks the glaſs veſſel into which it is ejected, and diſſolving it, a precipitation of ſiliceous matter takes place, and the water diſappears. This gas diſſolving glaſs (perhaps by uniting itſelf with the alkali uſed in making glaſs) is uſed in ornamenting window and other glaſs, with landſcapes, foliage, &c. &c. and engraving arms, creſts, cyphers, &c.

Oxygen gas (called hitherto dephlogiſticated air, vital air, empyreal air, &c.) is derived from the principle of acidity, and is only that principle united with caloric or fire. It forms one-third of the maſs of the atmoſphere, and is the principle which ſupports flame and animal life; for neither can exiſt without it. It is a conſtituent part of every kind of calx or oxyd, is capable of being expelled from them by heat, and is ſtrongly imbibed from the atmoſphere by metals reducing to oxyds. If air be confined over boiling mercury, the ſurface of the mercury will calcine into red globules, and the air will be diminiſhed, and its reſiduum noxious—the globules heated in a glaſs retort will give back the vital air they had imbibed, and this being mixed with the noxious reſiduum, will give the mixture of the ſame purity as at firſt. From nitre, or mangane ſe, minium or any oxyd, moiſtened with an acid, vital air is expelled by heat; to the baſis of this air (or its oxygen) iron has a particular affinity; therefore ignited iron put in a jar of this air, has its caloric or light diſengaged ſo rapidly as to dazzle the ſight! In this experiment the iron acquires weight, is reduced to finery cinder, and the remaining air is ſaid to have loſt the ſame weight the iron has acquired. —This wonderful air is abſorbed by the blood in breathing, and contributes to its red colour:—hence expired air is very different from inſpired air, being azotic and carbonic in coming from the lungs, and having depoſited its oxygen and latent heat in the blood. Hence the difference of colour in the venal and arterial blood——the danger of breathing azotic or mephitic air——and the cures performed by breathing air duly oxygenated.——This air is alſo procured by expoſing freſh leaves in an inverted glaſs of water, to light. Indeed all ſubſtances, vegetable, animal, or mineral, mixed with nitrous acid, and expoſed to a proper heat, give vital air, if not mixed with inflammable or carbonic matter.

From the ſmoke, putrid effluvia, calcination of metals, and breathing of animals, the air muſt be continually contaminating and unfitting for reſpiration. Providence has wiſely made the vegetable kingdom the cure for this evil; for plants imbibe nutrition from putrid and azotic air at their leaves, as may be ſeen by the ſuperior vigour in plants growing near large cities; by their growing on walls without earth, and by green plants put in noxious air, which imbibe nouriſhment, and cure the air at the ſame time.

Azotic air, is an heterogenous aſſemblage of exhalations from every ſubſtance capable of being ſublimed by the heat of the ſun. It forms two-thirds of the maſs of our atmoſphere.

END OF THE FIFTH LECTURE.

LECTURE VI.

Hydroſtatics.

THIS branch of Philoſophy treats of the *nature*, *gravity*, *preſſure*, *and motion of fluids* in general, and of weighing ſolids in them. *Water* is believed to conſiſt of *round* and *hard* particles; this ſeems proved by putting ſalt in water without increaſing its *bulk*; by the *round* pores of aquatic plants; and the *Florentine experiment*, which forces water through the pores of a copper ball: hence 'tis evident *there are vacuities in fluids*. No fluid can be preſſed into a *leſs ſpace* than it naturally poſſeſſes, except *air* and *ſteam*.

Fluids are ſaid to be *perfect* or *imperfect*, as their parts ſlide with more or leſs eaſe over one another, therefore quickſilver is a moſt perfect fluid. Water being of the *imperfect* kind is ſeldom *pure*: It adheres to any ſubſtance it meets with, mixes with its particles, and thence becomes impregnated with whatever *ſtrata* it runs over: If water has any thing alkaline in it, the *ſyrup of violets* turns it *green*; if any thing acid, the *ſyrup* turns it *red*; if it has run over *iron ſtone*, or *iron ore*, a ſolution of *galls* turns it *black*, and if alum, *oil of tartar* turns it *thick*, &c.—— Hence water impregnated with lime-ſtone, and ooſing ſlow amongſt moſſes, leaves, &c.—as the water evaporates, the ſtony matter adheres to theſe ſubſtances, and aſſuming their ſhapes, gives that variety of whimſical petrefactions we meet with in Derbyſhire, the dropping well at Knareſborough, &c.

Water being *incompreſſible* will not be more *denſe* at the *bottom* than the *top* of the ſea; but will have the wonderful property of preſſing *upwards* and *ſideways*, as forcibly as *downwards*, in proportion to its *perpendicular height*, without any regard to its *quantity*; for as each particle is quite free to move towards that part on which the preſſure is *leaſt*; no particle or quantity of a fluid can be at reſt till it is *every way equally preſſed.* A fluid may therefore be conceived as made up of *perpendicular columns of particles*, and as divided into *imaginary ſurfaces* each an inch or more from one another, the loweſt preſſed with the weight of *all* the reſt, &c. hence the pipe fixed under the *moſt* ſurfaces will diſcharge the *moſt* water, &c.

To prove that fluids preſs in all manner of directions alike, take four *glaſs tubes*, open at both ends, but bent into all kinds of angles; if theſe be put in water nearly to their tops, the water will riſe in them to its own level. Or take a veſſel full of water, with a hole at the *bottom of its ſide*, of the ſame ſize as one in its *bottom*, and the two holes will be found to diſcharge the ſame quantity of the fluid in the ſame time.

That fluids preſs in proportion to their depth, without any regard to their quantity, is evident, 1. From a *bladder* tied flaccid over one end of an open *cylinder of glaſs*; if water be poured into it, the bladder will bulge *downwards*; if then it be immerſed in a veſſel of water till the ſurface of the water within the cylinder be *even* with that in the veſſel, the bladder will then be *flattiſh* as if it were not preſſed at all, for indeed it is then preſſed equally. If the cylinder be plunged *deeper*, the bladder will be preſſed *upwards*, ſhewing that bodies ſwim merely by the force of the pillars of water under them endeavouring to riſe to their level. 2. *Lead* is about 11⅓ times heavier than its bulk of water; if therefore a piece be held tight to the mouth of a cylinder (open at both ends), by a ſtring within the cylinder, and let down into water above 11 times its thickneſs, the ſtring may be looſed, and the upward preſſure of the water will hold the lead to the cylinder; but if the cylinder and the lead be raiſed till the lead is not 11⅓ times its thickneſs below the ſurface of the water, it will then fall off and ſink. 3. If a cube of 34 inches, open at one end, and filled with quickſilver, have its open end immerſed in a baſon of quickſilver, hung ſo by ſtrings that it may be *let down* into a deep veſſel of water, according to the depth the veſſel is *ſunk*, the mercury will *riſe a fourteenth part* in the tube, and demonſtrate that quickſilver is fourteen times heavier than water. 4. If lead with a *flat upper ſide* be laid on the bottom of a veſſel, and a piece of *flat* wood be held on while the veſſel is filling with water; if no water can get in between the lead and the wood to form an *upward preſſure*, the wood will be held on the lead by its own weight and that of the water upon it. 5. If an *empty bottle*, juſt made ſo heavy as to ſink in water, be corked, and ſuſpended at one end of a balance, and, with its cork pulled out, be immerſed in water and filled, it will require as *much weight* in the oppoſite ſcale to pull it up, as will weigh all the water in it, which ſhews that fluids weigh juſt as much in their *own* element as out of it. 6. If a ſmall tube 30 inches long, be open at both ends, and to one end (bent to a right angle) has a *large bladder* tied; if then the bladder be put in a box, and a board be laid on it with 25 or 30lb. weight upon it, and water be poured into the tube, the bladder will raiſe the weights, though the bore of the tube ſhould be ſo ſmall as not to hold an ounce of water. 7. *The preſſure of a fluid upon the bottoms of all veſſels whatever, is proportional to their baſes and perpendicular height, without any regard to the quantities they contain*; for if on a looſe piſton ſuſpended on a balance, a column of water of a foot be weighed, it will be found to weigh as much as a column of water of the ſame height, though contained in a hanging veſſel that holds ten times as much. 8. If a *ſmall tube* be joined to a *very large one*, and the whole be bent in the bottom ſo that the two parts may be either *parallel*, or make *any angle*, water may be poured into *either tube*, and it will juſt riſe as high in the *other*, even though one ſhould contain ten thouſand times as much as the other does: This alſo ſhews that fluids preſs in proportion to their perpendicular heights, without any regard to their quantities; that water in pipes will aſcend to the *level* of *the ſpring* from whence it came; and that *jets* or *fountains* would riſe the *ſame height*, if not obſtructed by *angular turnings*, and the *reſiſtance of the air* into which they play.

Smoke does not riſe into air, becauſe the air where it is produced is heavier; it is carried up a chimney by heated air paſſing through and over the fire, and being cooled above the chimney, ſubſides into the ſtreets and houſes, in ſoot and duſt; if the ſmall neck of a bolthead, full of water, be immerſed in a glaſs of wine, the *lighter wine* will aſcend into the bolthead, and the *heavier water* deſcend into the glaſs. For the ſame reaſon, a body ſpecifically (or bulk for bulk) *heavier* than water will ſink in it; a body of the *ſame weight* will lie indifferently any where in it; and one ſpecifically *lighter* will of courſe ſwim in it.

Smoke is forced up a chimney by the air in the room preſſing to the rarefied air *in* the chimney;——hence, the patent ſtoves, contracting the fire-place, oblige the air to ruſh *in* with great violence, and thereby it overcomes more effectually any wind that forces the ſmoke *down* the chimney.——Kitchen, or other open chimnies, are very liable to ſmoke with winds coming *over*, or boſoming *againſt* a taller houſe, church, tree, &c.——becauſe the ſmoke riſing very ſlow and languidly in the open air, or wide chimnies, is eaſily puffed down by the wind, if a ventilator or feathered covering do not prevent it.

If a ſtick be counterpoiſed on a ſcale-beam by water, and after that immerſed in a veſſel full of water, it will cauſe ſo much of the water to flow over the brim as will be ſupplied by *that* in the oppoſite ſcale: Hence it is evident a *ſhip* diſplaces juſt ſo much water in the ſea as is equal to its own weight and cargo: And hence alſo the *ſtrength of wood* may be judged of; for if a piece of oak of a foot long be immerſed in a narrow veſſel of water, it will be found to ſink about eight-tenths of its length; beech about ſeven-tenths; mahogany ſeven-tenths, &c.

A ſolid body, heavier than its bulk in water, will loſe juſt ſo much of its weight when ſuſpended in it, as its bulk of water weighs: But the weight loſt by the ſolid is communicated to the fluid. Hence if the weight of a body in air be divided by what it loſes in a fluid, the quotient will ſhew how much heavier it is than its bulk of that fluid, or its *ſpecific gravity.* By this trial, *pure gold* is found to be 19,637 times as heavy as its bulk of water: *Guinea gold* 17,793 times as heavy; but pure platina is from 22 to 24 times as heavy as its bulk of water: *Quickſilver*, 14 times: *Lead*, 11,325 times: *Standard-ſilver*, 10,535: *Copper*, 9: *Plate-braſs*, 8: *Steel*, 7,85: *Iron*, 7,645: and *Block-tin*, 7,32. A cubic inch of braſs loſes 233$\frac{1}{3}$ grains of its aerial weight in water: In proof ſpirits it loſes 235 grains; therefore a cubic inch of water weighs 233$\frac{1}{3}$; and a cubic inch proof ſpirits 235 grains: And the ſpecific gravities of *pure ſpirits*, *proof ſpirits*, and *water*, are as 840,923 and 1000. From hence may be conceived the uſe of the hydroſtatic balance.

A *pipe* fixed *four times* as deep below the ſurface of a fluid as another of the ſame diameter, will diſcharge *twice* as much in the ſame time; if *nine times* as deep, it will diſcharge *three times* as much, &c. agreeable to the ſquare root of the depth: And the *velocity* with which a fluid ſpouts at any depth below the ſurface, is equal to that which a body falling *that height* would acquire. Pipes alſo diſcharge a fluid (when placed at equal depths below the ſurface) agreeable to the ſquares of their diameters, *i. e.* a pipe *twice* the diameter of another will diſcharge *four times* as much of the fluid, in the ſame time; *thrice* the diameter, *nine times* as much; *four times* the diameter, *ſixteen times* as much, &c. A ſhort pipe in the bottom of a ciſtern will diſcharge one-third more water than a hole of the ſame bore in the ſame time.

The preſſure of water againſt banks, the ſides of containing veſſels, &c. is in the proportion of falling bodies, viz. if the preſſure againſt the firſt inch deep of the veſſel be one pound, it will be three pounds preſſure upon the inch below that; five pounds againſt the inch below that; ſeven pounds againſt the inch below, &c. ſo that preſſure againſt banks, flood-gates, &c. is as the ſquare of the depth, *i. e.* if the preſſure be one pound againſt the uppermoſt inch, it will be four pounds againſt two inches deep; nine pounds againſt three inches deep; ſixteen pounds againſt four inches deep; twenty-five pounds againſt five inches deep, &c.

Fluids *preſs*, or *reſiſt*, according to their *denſity*; and hence a boat will carry more on *ſalt* than *freſh* water. *The hydrometer* is meant to ſhew this; it is buoyed up by *ſalt and water* mixed with *vinegar*, &c. but ſinks in *wine*, *ſpirits*, &c. according to their lightneſs; and hence it is uſed for trying the lightneſs or ſtrength of liquors; though heat, cold, and mixtures, make this a very fallacious inſtrument.

A *ſyphon* acts agreeably to that *equal ſtate* which nature affects through all her operations; it will not run unleſs the height of water in the *outer* leg be greater than that of the *inner* leg above the water in which it is immerſed; as the water falls, therefore, from the *outer* leg, it will make a continued *vacuum*, and of courſe the *preſſure of the atmoſphere* on the ſurface of the water will force it through the ſyphon in a *continued ſtream*, if kept free from that lodgment of air which frequently takes place on the top of the ſyphon. By the *Tantalus cup*, and *fountain at command*, the cauſe of *intermitting ſprings* is explained thus:

Clouds, being attracted by the mountains, give a continued ſupply to thoſe reſervoirs of water which are frequently found in the bowels of mountains, and which ſupply *ſprings* in general: But ſhould the channel from one of theſe reſervoirs be formed like a *ſyphon*, of courſe the ſpring which proceeds from it will *ebb* and *flow* like the ſea, as thoſe in Derbyſhire, Berkſhire, &c. but by no means ſo regularly.

The action of the *common pump* depends on the *preſſure of the atmoſphere*. When the piſton is drawn up, the column of air upon it is alſo lifted, and a vacuum is formed underneath it, the preſſure of the atmoſphere on the well will then force the water up the pump 33 feet, but not higher; which ſhews that a column of water of *that* height is equal to the weight of a column of air, of the ſame thickneſs, reaching from the earth's ſurface to the top of the atmoſphere. Therefore at any diſtance above the ſurface of the well, leſs than 33 feet, the piſton will work, and water from thence may be lifted to any height whatever, if the pump be ſtrong enough. In a *forcing pump*, the piſton is a *ſolid plunger*; it raiſes the water above the ſucking-valve as in the laſt, but when the plunger deſcends (as the water cannot return through the valve back again) the plunger forces it into a larger air veſſel, which communicates with the body of the pump above the ſucking-valve; and as by this force the air in the veſſel becomes condenſed, its re-action on the water cauſes it to flow through a ſmall pipe in a continued ſtream. The engine for extinguiſhing fires conſiſts of two ſuch forcing pumps, with their air veſſels.

The *lifting pump* can only be uſed in deep water, as its piſton is worked by a rod going in at the bottom, and faſtened to a frame coming up each ſide of the pump; This piſton has a valve opening upward, and it works below the ſurface of the water in which the pump is immerſed, and thence has no occaſion for the air's preſſure, or a ſucking-valve. This pump is generally equipt with an air veſſel as the laſt. On this principle engines are made for raiſing water above the level of rivers or ſprings, as at Marly; but if three pumps are worked in any engine by a tripple crank, and all of them throw their water into one pipe, there is no occaſion for an air veſſel, becauſe there will be always one or other of the piſtons acting, ſo as to force the water out in a regular ſtream,

Archimedes' ſcrew pump raiſes water by its endeavour to fall—'tis three or four hollow threads of a ſcrew wound round a ſolid cylinder; it muſt riſe out of the water ſloping, ſo that the threads may all incline downwards;

then, when it is turned round, water will riſe in it, but to no great height.

The *upright cylindrical mill*, by Dr. Barker, is a tall tube of wood or metal, twenty feet high, and about five inches diameter; it ſtands on a point perpendicularly, and has to its bottom two or more horizontal arms, or tubes, fixed, of about ſix feet long, communicating with the upright tube, and perforated with holes, one in each arm and on the ſame ſide in each; through theſe holes the water which flows in at top, ſpouts out, and giving a puſh to the air, and preventing the water's preſſure on that ſide the arm, forces the whole machine round, and carries a millſtone at top, or pumps, or any thing elſe capable of being moved by a circular motion. This, however, is rather an hydraulic curioſity than uſeful.

The *bucket engine*, for raiſing water by pumps out of mines, &c. is well calculated for ſituations where the ſtream that carries it has three yards of fall, and is too ſmall to carry a wheel: The bucket hangs on one end of a beam like that of a fire engine; and at half the diſtance from thence to the fulcrum hangs the pump rods; on the other end of the beam hangs the counterpoiſe, rather heavier than the empty bucket, and a column of water on the piſton; but when the bucket is filled by the ſtream, *it* is heavier, and deſcends; the bucket hangs on centres a little on one ſide its centre of gravity, ſo that one ſide is heavier when empty, and the other when full, and being unlocked by its deſcent, its unequal poiſe turns and empties it; and then, it aſcends and opens a valve which again lets the ſtream into it, and makes it deſcend again. This motion works the pumps.

Two forcing pumps, for ſupplying houſes with water, are alſo worked by an engine of ſimilar principles, but with ſtill greater ſimplicity: A beam inclining downwards to each end from the centre on which it hangs, has a trough cut in it, from a diviſion in the middle down to each end, where buckets are fixed for receiving the water that works it, and which flows into the trough, firſt on one ſide the diviſion, and then on the other, as the ends riſe and fall: When one bucket deſcends, the valve in its bottom falls on a pin, which opens it, and lets out the water; mean while the ſtream is filling the other bucket, which, when full, deſcends in like manner, and each end works a forcing pump.

Several Models to ſhew how a ſhip may pump herſelf.

The *fire* (or rather *ſteam) engine*, is one of the nobleſt preſents that art has made to the neceſſities of mankind! When the particles of *water* are ſeparated by fire, they compoſe an *elaſtic vapour* called *ſteam*; this vapour is capable of occupying 14,000 times the *ſpace* it did in its ſtate of *cold water*; it is of force ſufficient to drive away the air, and it may be condenſed or brought back to water again by *cold*. Hence a long hollow *cylinder* of iron communicates with a huge and cloſe *boiler*, half filled with water, by a neck which can be opened or ſhut by a ſliding valve, called a *regulator:* The *cylinder* is exactly fitted by a *piſton* made *air-tight*, that hangs on one end of a *beam* of timber about 20 feet long, and ſuſpended on a centre like a ſcale-beam; at the other end of the beam hang the *rods* which work the *pumps* in the bottom of the *mine*, and throw up a part of the water into a *reſervoir* on the top of the building: From this *reſervoir* there comes a *pipe* under and through the bottom of the *cylinder*, that by opening the cock (called the *injection cock)* plays a *jet* of cold water into the *cylinder* to condenſe the ſteam; after which this water falls through a pipe (with a valve opening outward) and forms the *hot-well:* Another pipe alſo, with a valve outward, called the *ſnifted valve*, is fixed near the bottom of the cylinder, and ſerves to let out the *air* or *ſteam* without letting it return. The *regulator*, or *injection cock*, is alternately opened and ſhut by a piece of timber hanging from the large beam; and a ſtream is let into the *boiler*, or ſtopped by a floating *copper ball* in the boiler, that regulates the height of the water. If now a *large fire* be put under the boiler, and the ſteam be let into the cylinder by opening the regulator, it will drive out the air, and poſſeſs the ſpace itſelf; but ſo ſoon as the *injection cock* is opened, a *jet* of *cold water* will play into the ſteam in the cylinder, and *condenſe* it into a *few drops*; hence a *vacuum* is formed in the cylinder, and the *preſſure of the atmoſphere* on the *piſton* will force it down to the bottom of it; the ſteam then being let in again will counteract the air's preſſure, and with the weight of the pump rods on the oppoſite end of the beam, bring up the piſton to the *top* of the cylinder. This action is repeated *fourteen* or *ſixteen* times in a minute, and works the pump in the mine. As the *friction* of this machine is very great, inſtead of reckoning 15lb. preſſure on every ſquare inch of the piſton, 8lb. will be found nearer. If then the weight of a column of water, the depth of the mine, and the diameter of the pump be calculated, the neceſſary diameter of the cylinder will be eaſily found.

The *fire engine with the inverted piſton* ſpares the expence of both a *beam and building*; the cylinder, with its open end downwards, ſtands over the pit or ſhaft of the mine, the boiler ſtands by its ſide, the *injection well* above it, and to its *piſton* the *pump rods* are faſtened. The *regulator* (of great ſimplicity) is the *injection cock* alſo. When the ſteam is let in at the top of the cylinder, and condenſed by the injection water, the *upward* preſſure of the atmoſphere forces the piſton from the bottom to the top of the cylinder, and the weight of the rods, and the ſtrength of the ſteam, force it back again. This motion works the pumps.

Watt's and Boulton's ſteam engine condenſes the ſteam, without cooling the cylinder by a jet of cold water, and thereby ſaves fuel. The ſteam is produced in a boiler as uſual—it paſſes into a double cylinder, and forces down the piſton by its elaſticity, for the rod of the cylinder works through a collar of leathers, and therefore the preſſure of the atmoſphere has nothing to do in this engine. When the piſton is at the bottom of the cylinder the ſteam-cock opens, and by the double cylinder, ſteam enters both above and below the piſton; ſo that it riſes in ſtagnant ſteam by the weight of the pump rods acting on the oppoſite end of the large beam. When the piſton arrives at the top of the cylinder, a cock opens that communicates with the vacuum formed in a pond of cold water; this draws the ſteam from *under* the piſton in a moſt perfect manner; and leaves the piſton liable to the preſſure of the ſteam *upon its top:* and as the ſteam may be made of much ſtronger preſſure than the atmoſphere, this engine is proportionably more powerful than the common engine.

Theſe, and many other hydraulic machines for various purpoſes, are too cumbrous to be removed from the ſtationary lecture-room.

END OF THE SIXTH LECTURE.

PATENT OFFICE LIBRARY

LECTURE VII. AND VIII.

Electricity.

ELECTRICITY, fire, and light, having many properties alike, have been thought but modifications of one and the ſame principle. Iron loſing its phlogiſton or fire by vitriolic acid, loſes, by the ſame proceſs, its electricity; proved by inſulating the proceſs, when a wire communicating with the efferveſcing mixture will betray ſigns of negative electricity. This moſt ſubtil fluid, ſeems more or leſs inherent in all matter—but ſome bodies conduct or tranſmit it, whilſt others ſtop its progreſs from one body to another. Glaſs, air, ſilk, gums, &c. are *non-conductors*, and called *electrics:* but metals, water, green wood, and moſt animal and vegetable ſubſtances, are *conductors*, and are called *non-electrics*. 1. If a long tube of glaſs be rubbed with warm ſilk, an atmoſphere of this fire will be formed all round it, and if a finger approaches the tube, the fire will come viſibly off the tube into the finger with a ſnap: The reaſon is, the friction collects the fire from the earth (its grand reſervoir), and the ſpark is the effort it makes to diſperſe itſelf again, and thereby reſtore its equilibrium. 2. If the ſame tube electrified, approach a *feather*, hung by a ſilk thread, it will *attract* the feather once; but if held to it again, will repel it. The ſilk will not conduct the electric fire; the equilibrium is, therefore, effected between the tube and the feather on the firſt approach; on the ſecond, the atmoſphere f the tube preſſing on that of the feather, drives the feather from it (for two bodies poſſeſſed of the ſame electricity univerſally repel one another;) but if the feather be ſuſpended by a flaxen thread, the electrified tube will always attract it, becauſe the fluid can make its eſcape up the thread, and thereby leave a continued inequality between them. A *large globe* or *cylinder* of glaſs, with a *ſilk cuſhion* covered with an amalgama of quickſilver and tinfoil, or zink, or aurum moſaïcum ſpread on black ſilk, ſaturated with mercurial ointment, to produce the friction; a *prime conductor* to take off the *electric atmoſphere* from the glaſs, and depoſit it in a *glaſs receiver* covered in and outſide with tinfoil to within two inches of the top, and a *wheel* to put the cylinder in motion, is called the *electric machine*, or *fire pump*. An electric machine of great power is alſo made of oiled or gum'd ſilk drawn between rubbers of cat's-ſkin with the fur on. When a machine is put in motion, it diſturbs the equilibrium of the *electric* fire about it, and from thence the whole of its phœnomena proceed, as may be proved by experiment. 1. If a perſon touch the electrified conductor, the fire will eſcape from it through the perſon into the ground, with a flaſh and report. 2. If any number of perſons take hands, and the firſt perſon holds a chain which communicates with the *outſide* of the receiver, and the laſt perſon touches the communication with the *inſide* when the phial is charged, the fluid will reſtore itſelf through all the company at the ſame inſtant, giving each a ſhock at the wriſts and elbows, in its paſſage back again to the *outſide* of the phial. 3. If a perſon ſtands on a ſtool with *glaſs feet*, and holds a chain faſtened to a conductor, on turning a machine, and touching him, ſparks may be brought out of every part of his perſon and cloaths, and if he touch warm ſpirits, or gunpowder, with his finger, they will take fire; which ſhews that the electric fire is chiefly pumped from the earth, and cannot return to it again through glaſs. 4. If a ball be hung on the conductor, and a plate of *bran* or *leaf gold* be placed under it, on electrifying the ball, the bran will be alternately attracted to and repelled from it, in a beautiful ſhower: here the particles of the bran are carriers, as it were, of the electric fire from the ball to the plate: And if two *bells* be hung on the conductor, one by a flaxen thread, and the other by a ſilk thread (having from it a chain to the table), if a ſmall *clapper* be hung between them on a ſilk thread, it will carry the fire from one to another, and thereby ring both. 5. *Electrified feathers* ſpread out their threads radiantly; if a round body be held to them they *cling* to it and depoſit their fire; but if a point be held near them they ſhrink at once; hence the reaſon why the wire conductors riſing from the ground above the tops of houſes, terminate in points to receive with more eaſe the *lightning* from the clouds, and thereby prevent its miſchief. 6. If *wires* fixed like the ſpokes of a wheel be ſuſpended on their centre, with their points bent all the ſame way, and in the plane of the circle; on being electrified, the effluvia flowing from the points will ſtrike ſo forcibly upon the air as to force the wheel round with great rapidity: Hence a ſimple and pleaſing electric orrery is put in motion,—and various mills and other devices. 7. *Water* and *ſalt* (like the cylinder and cuſhion) will collect the electric fire when put in motion; for one is an *electric*, and the other a *non-electric* body; hence the *ſea* itſelf becomes, as it were, an *huge electrical machine* when violently agitated by winds; collecting on its troubled ſurface the fire from beneath, and looking in the night as if it was all in flames. *Clouds* raiſed from a ſea ſo circumſtanced, muſt needs contain more of the electric fire than clouds raiſed from the land, or calm ſea; if therefore two clouds meet, fraught with *unequal portions of this fire*, the cloud *more* electrified will depoſit its abundance in the cloud *leſs* electrified, and with a flaſh of lightning reſtore the equilibrium; this fire driving to a diſtance the air that ſurrounds it—the ſtroke formed by the return of that air is *thunder*. Some think putrid fiſh, others animalculæ, or an eaſt wind, the cauſe of the luminous appearance of the ſea. If a cloud attracted by a neighbouring mountain contain *more* electric fire (matter for matter) than the mountain, the lightning will dart from the cloud to the mountain, and vice verſâ; hence, if an electric cloud comes too near a *tower*, *tree*, *houſe*, &c. and they are not wet, the negative of one will meet the poſitive of the other in an effort to reſtore the equipoiſe, and if greatly obſtructed in their paſſage, will, perhaps, break all non-conducting ſubſtances in their way to pieces; to ſtand very near a tree is, therefore, dangerous in a thunder ſtorm; and ſhews alſo the utility of having a conducting wire reaching from a few feet above the building into the ground, down which the equilibrium will be reſtored without danger; and if the wire does not touch the ground, a finger at that time applied to the wire, will receive that *electric flaſh* much ſtronger than by a machine. A *kite* ſent up into the thunder-cloud by a wire, having a key tied to its end, and held by a ſilk ribband, will extract the fire from the cloud; it will come down the wire, and ſtream off the key to the ground in a beautiful but alarming torrent of fire.

'Tis thus, by weight and meaſure, the ALMIGHTY has appointed ſelf-phyſic for the diſorders of his works!

If a *capillary ſyphon* be made to decant water, it will fall from it in *ſmall drops*, but if the water be electrified it flows from the ſyphon in a *ſwift ſtream*. Hence 'tis found that a perſon *poſitively electrified* (*i. e.* having more electric fire thrown into him than his *natural quantity*, by ſtanding on a cake of wax, or a glaſs-footed ſtool, and touching an electrified conductor), has his *pulſe accelerated*. This acceleration has been found of great ſervice in *obſtructions*, *rheumatiſms*, *palſies*, &c. and the *electric ſhock* has been ſtill more ſucceſsful in removing *paralytic complaints*, *deafneſs*, *tooth-ach*, *numbneſs*, &c. Sparks drawn from chilblains, ſwellings, &c. have a great effect, and the aura from a wooden point has diſperſed the cataract of the eye.

The electrical fluid always goes the neareſt way, and chuſes the beſt conductors. A chain hung on a wall, and made part of the circuit from the *in* to the *outſide* of the charged Leyden phial, is luminous when the vial is diſcharged, and ſhews the road taken by the electrical fluid: but if a ſtraight wire touch the two ends of the chain, the chain will not be luminous, for the fluid will run inviſibly thro' the wire, as being the *nearer* road. If the wire be then removed, and a ſtick put into its place, the chain again becomes luminous in the diſcharge, as the fluid will rather go a longer diſtance than paſs through a bad conductor.

The electrical fluid induced on the inſide coating of a Leyden phial, draws an equal quantity from the outſide. 1. If the outſide coating of a phial conſiſt of pieces of tinfoil, not touching one another, the fire will be ſeen darting from one piece to another, till the charge is completed: when diſcharged the fluid will return, and make the whole outſide luminous. 2. A bottle, having its bottom coated on both ſides, and a cap cemented on its neck, with a valve; and from that cap a pointed wire going near the bottom of the bottle: If this bottle be exhauſted of its air (but not to a vacuum), it will be found a good conductor; and when the cap is held to the prime conductor, flames like the Aurora borealis will iſſue from the point of the wire to the inſide coating, and charge it;—but while an imperfect communication is made between the negative outſide and the poſitive inſide, the point receives the fluid, and exhibits only a ſtar on its point:—Hence a *receiving* point always exhibits a *ſtar*, and a *delivering* point *flames* in an imperfect vacuum. Rarefied air being ſo good a conductor, may not the ſun's electricity, when approaching the earth, be conducted by the thin air of the upper part of the atmoſphere towards the poles, and produce the Aurora or ſtreamers? For denſe air is a non-conductor, and muſt reſiſt the paſſage of electricity, as well as the greater centrifugal motion of the equatorial, than the polar parts of the earth. Perhaps the vicinity of the magnetic poles to the poles of the earth, may alſo promote a condenſation of the electric matter in the polar regions: For a ſtrong ſhock of electricity will give magnetiſm to iron, and prove they are relations. 3. On the cover of a large Leyden jar, fix a ſmaller jar, ſo that the *outſide* coating of the ſmall jar may have a metallic communication with the *inſide* coating of the larger;—the outſide coating of the ſmall jar becomes a conductor to the inſide of the big one, when held to an excited prime conductor; if when charged, one knob of the diſcharging rod be applied to the negative ſide of the large jar, and the other applied to the knob communicating with the inſide of the ſmall jar, a flaſh will iſſue from the contact (being the natural electricity of the inſide coating of the ſmall jar), by which the equilibrium of its two ſides becomes deſtroyed. Electricity will then riſe from the inſide of the large jar upon the outſide of the ſmall one. This balance is again reſtored by forming a metallic communication between the *in* and *outſide* coatings of the ſmall jar. By repeating this twenty or thirty times, the whole charge of the lower jar will be taken piecemeal out; and prove, that what electricity is induced on one coating of a jar, draws or impels a like quantity from the other. 4. If a rod of wire, 18 inches long, having a light knob at each end, and ſuſpended on an inſulated point, be placed ſo between the knob of a charged jar and a metal pillar, that when one knob touches the pillar the other may be ſix inches from that of the jar, then will the rod vibrate between the jar and the pillar, taking out the electricity ſo by little and little as to require ten minutes to complete the diſcharge. 5. If a Leyden phial be charged on an inſulated ſtool, having two pith balls hanging by fine threads projecting from its in and outſide coatings, the balls communicating with the poſitive coating will ſeparate; if then a finger touch the wire on which they hang, theſe balls will cloſe, and thoſe will open which communicate with the *negative* coating; touch that wire and the negative balls cloſe, and the *poſitive* balls open, &c. for an amazing number of times? ſhewing, that though glaſs will not conduct electricity, the electric influence can operate through the thickneſs of glaſs. 6. To ſuperinduce electricity on a looſe coating laid on plate-glaſs, touch the coating with the knob of a charged phial, then ſhake off the coating, and clap an inſulated metal plate on the place, touching it at the time of contact, then lift up the plate, and it will give a ſpark to the knuckle; place it on the glaſs again, and touch and remove it as before, and it will give another ſpark, and continue to do ſo as long as the apparatus is kept clean and dry; making perpetual electricity, by which phials may be charged, inflammable air-guns fired, &c. —— N. B. The plate of glaſs muſt have a fixed coating on the oppoſite ſide to the looſe one, and of the ſame ſize. This apparatus is called *Electrophorus*; and often inſtead of glaſs, a plate is made of ſulphur, ſhell-lac, reſin, &c. To prove that the natural electricity of bodies may be diſturbed by the near approach of excited electrics, let two projecting arms of inſulated wood have ſlips of tinfoil glued on them from end to end, and pith balls hanging from one end of each; if the two arms be placed in a line, with the ball end of one touching the end without balls of the other, and an excited electric be held within an inch of the end without balls, then will all the four balls part;——at that inſtant, if one ſtand be ſeparated from the other, the balls of one will be found in a negative, and the other in a poſitive ſtate, the balls fartheſt diſtant from the excited electric will be in the ſame ſtate as the electric, and of courſe repelled by it; the neareſt attracted, &c. Hence, if any part of an electrical cloud comes near the earth, it will diſturb the electricity in the earth, and drive it away; but if any other part of the cloud comes within a ſtriking diſtance of the earth,—the cloud will be diſcharged, and the diſturbed electricity will return with a force that frequently proves fatal to animals in its way.

Electricity is applied to *inflamed eyes, tumours, &c.* by a chain coming from the prime conductor ending in a point of hard wood; the point is held near the part by a glaſs handle, and an aura iſſues from it on the ſore, that often performs a cure. 2. Paralytic and rheumatic patients are relieved by ſhocks ſent through the ſide affected. 3. Obſtructions are often cured in both ſexes by poſitive electrification, *i. e.* by placing the patients on an inſulated ſtool, communicating with the prime conductor, and keeping them electrified for half an hour together, occaſionally drawing ſparks from them.

Some of the great and ſtriking effects of electricity (as a rival to lightning) are, 1. A large ſheep has been killed by the ſhock of three large jars ſent through its head. 2. A wire is ignited by ſuch a ſhock, its melted globules flying about, and its diſperſed oyxd in floculæ. 3. A tall pyramid, with a wire through it, all but at a looſe corner ſtone, where is a break in the wire; at this break an exploſion ſtrikes out the ſtone and demoliſhes the pyramid. 4. Stones forming breaks in models of domeſtic conductors alſo illuſtrate the danger of ſuch breaks in real conductors. 5. Two ſlips of glaſs, with pieces of leaf gold between them, when preſſed cloſe together, if a ſtrong ſhock be ſent through them, the glaſs is broke to pieces and enamelled with the molten gold. 6. One hundred pages of a book can be pierced through with a ſtrong ſhock, the perforation affords a phoſphoric ſmell, the exploſion between the poſitive and negative ſide of the jars takes place in the centre of the leaves, and hence a bur appears on both ſides.

Animal electricity is the lateſt diſcovery made in this wonderful agent in nature, and bids fair to explain *muſcular motion.* If a live frog be divided in the middle, its viſcera cleared away, the ſkin ſtript from its hind legs, and part of the back bone be left attached to them by the two nerves of thoſe legs; if then the legs be laid on tinfoil, and the part of the vertebræ on ſilver, and a communication be made between the two metals by a crooked ſilver wire, the legs inſtantly are convulſed, and ſtart up! though the animal may have been apparently dead half an hour!—— If the legs be put in one glaſs of water, and the vertebræ in another adjoining, on the ſilver wire touching the water in each glaſs, the legs and vertebræ inſtantly ſpring out of the glaſſes! The hearts of eels, flounders, and other cold animals have the ſame effect: and a human leg recently amputated, ſtirred its toes on being treated as above.

Though theſe facts have appeared in the Philoſophical Tranſactions, I ſee no attempt at an explanation.

END OF LECTURES SEVEN AND EIGHT.

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LECTURE IX.

Optics.

Hail holy light! *Offspring of heaven! Firſt born!*
Or of th' eternal coeternal beam;
May I expreſs thee unblamed? MILTON.

THIS *modeſty* of the *poet* becomes the dignity of ſo divine a ſubject.—*Light* is the bleſſing which gives poignancy to all others,——therefore the ſcience of *optics*, which immediately treats of it, muſt reflect part of its luſtre and importance. Plato defines light, *a rare and ſubtil flame*;" and perhaps it is but a diluted flame in a ſtate of great thinneſs or rarefaction. May it not be the inflammable principle perpetually let looſe from the ſun, and occaſionally from other luminous bodies?——May not theſe particles flowing from the ſun, enter into the texture of other bodies; give them the power of inflammability; and become fixt in them, till let looſe by the contact of bodies in actual inflammation?——Or, finally, that the incorporated rays of the ſun in bodies having affinity with them, may give them the power of inflammability univerſally; and that colour in bodies may ariſe from a chemical rejection of the colour reflected to the eye, while all the reſt are abſorbed into the body? I believe *light* to exiſt in the *abſence* of a luminous body, and that it is the *luminous body* that puts it in motion. The moſt general opinion is, that it flows immediately *from* the luminous body in ſtraight lines, in all manner of directions, and conſiſts of *particles* ſo infinitely ſmall, as to exceed all human comprehenſion. A *candle* will fill a ſphere of four miles in diameter, without the leaſt ſenſible loſs of its ſubſtance: But this light exiſted there before, and the candle only put it in motion; as if 1000 billiard balls touched one another in a line, and the firſt was ſtruck in the direction of the line, the whole would be put in motion. And if a *row of candles* ſtand parallel to a *black paper*, with a *pin-hole* in it, each candle (through that hole) will make a ſeparate ſpeck on the *paſte-board* a little behind it; ſhewing that light is repulſive of itſelf: that its particles are at a great diſtance from one another; and therefore croſs one another without joſtling or inconvenience. Theſe particles, by ſtriking the *retina* of our eyes, excite in our minds the idea of light: And when they fall upon bodies, and are by them reflected to our eyes, they excite in us an idea of the colour and ſhape of theſe bodies.

In a room *perfectly dark*, if the hand (or any thing) be put into light, and then taken into the dark room, it will be luminous ſome time, as if covered with phoſphorus.—Calcined oyſter ſhells taken out of the light into the dark room, exhibit the colours of the rainbow, &c. ſhewing that light ſtriking upon bodies, excites their latent light, and makes it viſible, as one candle is lighted from another. Or that light ſticks to bodies plunged in it, as water does to the hand.

We cannot ſee through the bore of a bended pipe; which proves that light moves in ſtraight lines in *every medium of uniform denſity*. But when they paſs *obliquely*, out of one medium into another, which is either more *denſe*, or more *rare*, they are *refracted*, or bent towards the denſer medium, more or leſs, as they fall more or leſs obliquely on its ſurface. To prove which, put a ſhilling in the bottom of an empty veſſel; ſtand ſo far from it that the veſſel may hide the ſhilling; if water be then poured into it, the ſhilling will again be ſeen.

Hence we are deceived in the depth of clear water: A ſtraight ſtick put into water will appear crooked; and the *ſun's* rays being bent by paſſing through our atmoſphere, we ſee him in the *horizon*, before he riſes, and after he ſets in it. When *rays* fall perpendicularly on any tranſparent medium, they paſs ſtraight through without any medium.

Glaſs is generally ground into eight different ſhapes for optical purpoſes. 1. A *plane glaſs* is flat, and even on both ſides, and of an uniform thickneſs; will refract the rays of light, but not collect them into one focus. 2. A *plano-convex*, is flat on one ſide, and a portion of a ſphere on the other. When parallel rays fall directly upon it, they paſs through it, and are ſo refracted, as to unite in a point called its focus, juſt ſo far behind it, as is equal to the diameter of the ſphere of which it is a part. 3. A *double convex* is convex on both ſides: Parallel rays paſſing through it *converge* or meet in a focus, at half the diſtance they do through the *plano-convex*; and as the heat of all thoſe rays are collected in that focal point, it will burn, melt, or calcine all opaque bodies. 4. A *plano-concave* is flat on one ſide, and concave on the other. 5. The *double concave* is hollow on both ſides, and parallel rays paſſing through *diverge* or ſpread out agreeable to the laws of refraction. 6. A *meniſcus-glaſs* is convex on one ſide, and concave on the other. 7. A *flatted plano-convex*, or multiplying glaſs, has its convex ſide ground into ſeveral flat ſurfaces. And, 8. The *priſm* has three flat ſides, and viewed endwiſe appears like an equilateral triangle. The *priſm* held obliquely to a ray of light in a dark room will affect its ſmalleſt *particles* the *moſt*, and ſhew them to be a fine *violet colour*; it will aſſemble the next in ſize cloſe to the firſt, and ſhew them to be of an *indigo colour*; the next *blue*; the next *green*; the next *yellow*; then *orange*; and at laſt the *red*, which conſiſts of the largeſt particles, and therefore by the momentum of their motion, the leaſt capable of being attracted out of their way. 'Tis wonderful that theſe colours occupy ſpaces on the ſcreen on which they are thrown by the priſm, exactly proportionate to the diatonic ſcale of the *ſeven notes of muſic!* If in the rays ſo divided a *double-convex lens* be put, it will bring them into one point that ſhall be perfectly white; which accounts for the *white appearance of light*. As *white* is therefore a compoſition of all colours, ſo *black* is a privation of them all, and properly *no colour*; blue is the natural colour of the atmoſphere, ſo that diſtant mountains look blue, by being ſeen through a medium of that colour. All bodies appear of that colour whoſe rays they reflect moſt; as a body is red when it reflects the *red rays*, and abſorbs the reſt. Two, or more, colours may be quite tranſparent by themſelves, yet become dark when put together. Thus, if *ſpirits of wine* be tinged *red*, and put in a ſquare bottle, every object ſeen through it will be *red*; becauſe it only ſuffers the red rays to paſs through it, and ſtops the reſt. If another bottle be tinged blue, all objects viewed through it will be blue for the ſame reaſon: But if the two bottles be held together, the object can no more be ſeen through them; for whatever rays paſs through one bottle to the eye, will be ſtopped by the other, &c. Rays of light ſuffer different degrees of refraction, by falling more or leſs obliquely on the *priſm* or *convex lens*, *&c.* and are thereby ſeparated as above; this happens to them in paſſing through *drops of falling rain:* For being *reflected* towards the eye from the ſides of thoſe drops which are fartheſt from the eye, and again *refracted* by paſſing out of theſe drops into the air, they come in refracted directions to the eye, and make all the colours to appear ſucceſſively in the form of a fine arch in the heavens, which is called the *rainbow*. All drops paſſing through an ideal plane in the ſhower, refract a certain colour to the eye—paſſing through another a little lower, they refract another, &c. ſo the bow appears permanent while the ſhower laſts.

Light is *reflected* by the *repellent* quality of bodies, and flies back from poliſhed ſurfaces, like a ball thrown againſt a hard and ſmooth plane: If a ſtick ſtand perpendicularly on the plane, and the ball be thrown obliquely on the plane near its foot, it will rebound on the other ſide the ſtick, and form an angle with it, equal to that in which it was thrown; the firſt of theſe is called the *angle of incidence*, and the other the *angle of reflection*. If upon a *plane looking glaſs* a ray falls from any object, if a perpendicular be erected there, and the eye go off ſuch a diſtance as to form the *ſame angle* on the other ſide of it, the object will be ſeen in a ſtraight line behind the glaſs,—for it is an axiom in optics, *that we always ſee objects in that line of rays that come to the eye laſt*. Hence I ſee my whole perſon in a glaſs but *half* its length; for the rays from my feet ſtriking upon the bottom of the mirror, will form the *angle of reflection* in my eye the ſame as if it were the *whole* length, &c. Hence alſo the effects of *diagonal mirrors*, *opera glaſſes*, *cameras*, &c. Parallel rays falling on a *concave mirror* will be reflected alſo agreeably to thoſe *angles*, and meet in a point at half the diſtance of the mirror, from the centre of its concavity; if the rays proceed from a hot ſun, his image will likewiſe be found in that point; and burn. The rays which proceed from any ſmall *terreſtrial object*, *come diverging* to the mirror, and therefore will not be *converged to a point* at half the diſtance of the mirror's ſurface from the centre of its concavity; *but farther from that ſurface*, the image will be leſs than the *object*, but will be ſeen *inverted*, and hanging pendant in the air, quite diſtinct, by an eye placed oppoſite the mirror. If the *object* be *in* the *centre of the mirror's concavity*, the *image* and *object* will be *together*, and of *equal bulk*: Therefore when the object is more remote than the centre of concavity, the *image* will be *leſs* than the *object*, and between the *object* and *mirror*: But when the object is *nearer* than the centre of concavity, the *image* will be *more remote*, and *bigger* than the object. The angles of *incidence* and *reflection* alſo account for the *ſmall image* in a *convex mirror*.

The *human eye* is lodged in a bed of fat, and ſecured in an hollow orb of bone;—'tis moved by *muſcles* which act on its outſide like *pullies*, and conſiſts of *four coats*, and *three humours*. The coat in which the *body* of the eye is contained, is called the *ſclerotica*; it is a *large portion of a* *globe*, very ſtrong, and of a non-elaſtic nature;—that part which *completes the globe* on the *fore-part* of the eye, is the *cornea*; it bulges a little forward out of that ſhape, and is a fine tranſparent membrane. Next within the ſclerotica is that called the *choroides*, which ſerves, as it were, for a *ſoft lining* for the other; and within this is ſpread a fine expanſion of the optic nerve, like a net, called the *retina*, upon which are painted, as in a *camera obſcura*, *the images of all well-enlightened objects we look at.* The *iris* is compoſed of two ſets of muſcular fibres, which dilate or contract the *hole* in it, called the *pupil*, ſo as to adapt it to a ſtrong or weak light. The *adnata* or *conjunctiva*, is the white of the eye, a fine membrane that *folds under the eye-lid*, and joins to it. Under the *cornea* is a fine tranſparent fluid like water, and thence called the *aqueous humour*: It gives the protuberant figure to the cornea, and goes through the pupil. Behind this lies the *cryſtalline humour*, ſhaped like a double-convex glaſs, tranſparent as cryſtal, of the conſiſtence of hard jelly, and which converges the rays that paſs through it to a focus, on the *retina*. It is incloſed in a fine tranſparent membrane, from which proceed radiant fibres, called the *ligamentum ciliare*, all round its edge, and joined to the outward edge of the *iris*: Theſe fibres, by a power of contracting and dilating, alter the convexity of the *cryſtalline humour*, and ſhift it a little *backward* or *forward* in the eye, to ſuit it to the different diſtances of objects *(an admirable proviſion!)* The *cryſtalline humour* is bedded on the *vitreous humour*, which fills the whole of the other part of the orb of the eye, and is tranſparent like glaſs; this is the largeſt of all in quantity, and is much of a conſiſtence with the white of an egg. The *optic nerve* comes from the *brain*, through the *ſclerotica* and *choroides*, on that ſide the eye next the noſe; and is incloſed on the outſide the eye by coats proceeding from the *pia* and *dura mater*, and of which the *ſclerotica* and *choroides* are but a continuation. Theſe are the parts of this wonderful organ!

Rays from any enlightened *object* ſtream upon the *retina*, and there paint it invertedly, as may be ſeen by cutting off the three coats from the back part of a freſh bullock's eye and putting a piece of white paper over that part: If the eye is then held before any bright object, an inverted picture of it will be painted on the paper. The *optic nerve* incloſes a *blood-veſſel*, which renders objects inviſible that fall on it; how wiſely therefore is it placed on one ſide of each eye! that the ſame parts of an image which fall on the optic nerve of *one* eye, ſhould not fall on the *other!* If three patches are placed at a foot diſtance from each other on a wall, if the *right* eye be covered, and the *left* look ſteadily at the right-hand patch, the middle patch will diſappear, becauſe it falls on the artery in the optic nerve.

The nearer any object is to the eye, the larger is the angle under which it is ſeen; therefore an object looks twice larger at *one* than at *two* miles diſtance. Hence the uſe of *convex-glaſſes*; which by increaſing *this* angle, make *minute objects* viſible; and when the *humours* are grown ſo flat in decayed eyes, that the picture falls behind the retina, can bring the rays to converge ſo, that the picture ſhall be brought back, as it were, to the *retina*. Hence, alſo, the reaſon that the *too round* eye requires the *double concave* glaſs, by its divergency, to remove the image from the vitreous humour forward to the retina. Hence the theory of ſpectacles.

The *ſingle microſcope* is only a ſmall convex glaſs having the object placed in its focus; and the eye at the ſame diſtance on the other ſide. Its magnifying power is thus calculated: A good eye cannot ſee any object diſtinctly at leſs than ſix inches diſtance; if this be divided by the focal diſtance of the glaſs, the quotient will be how much the diameter of the object is multiplied.

The *double microſcope* conſiſts of an *object glaſs* and an *eye glaſs*, between which the image is formed and magnified, by having the object a little further from the object glaſs than its principle focus; this image, brought ſo near, is viewed by the eye through the eye glaſs. If each glaſs magnifies *ſix times* (as by the laſt calculation) then is the object magnified *thirty-ſix times* by both. This inſtrument is equipt with a mirror, which, by the *angle of incidence* and *reflection*, throws up a light on the *underſide* of the object; which object, being placed in the focus of a *moveable mirror*, has its *upperſide* enlightened alſo.

The *ſolar microſcope* is placed in a round hole in a ſhutter that only admits, into a dark room, a ſmall cone of rays: that theſe rays may be ſent ſtraight through the tube, a plain mirror on the *outſide* is ſo fixed, as to reflect them in; they then paſs through a large convex lens; after which, they fall upon, and enlighten the object, which is placed in the focus of a *ſmall magnifier*, through which they carry a large inverted image of the object to a white ſcreen, placed at any diſtance for its reception.

A *refracting teleſcope* may be made of *two convex glaſſes*, viz. an *object glaſs* and an *eye glaſs*: if the focus of the *eye glaſs* be in the ſame part of the tube where the image is formed by the *object glaſs*: But then the image will be inverted, and therefore 'tis only ſuitable for celeſtial objects. The magnifying power of this teleſcope is as the focal diſtance of the *object glaſs* to the focal diſtance of the *eye glaſs*: Therefore if the *former* be divided by the *latter*, the quotient will expreſs the magnifying power, and ſhew, that if the focal diſtance of *each were alike*, the magnifying power of the teleſcope would be nothing; and that this magnifying power would increaſe with its length, for the greater the focal diſtance of the object glaſs, the leſs may be the focus of the eye glaſs.

A *refracting teleſcope*, that will ſhew objects in their natural poſture, muſt have *two equal convex glaſſes* added to the eye glaſs, and all three muſt ſtand at double their focal diſtances from one another. As theſe three do but, as it were, compoſe one eye glaſs, the magnifying power of this teleſcope may be calculated as the laſt.

Dollond's acromatic teleſcope is formed on the ſame principles, only its object glaſs is much larger, and is compoſed of two joining glaſſes of different denſities, one a *plano concave* and the other a *double convex* that fits into the other's concavity. Theſe make the field of view larger, and, by taking off the coloured rays, the image becomes bright and diſtinct: For as the rays of light do not all bend alike in paſſing through glaſs, but are ſome more refrangible than others, a ſingle object glaſs has the priſmatic effect to tinge the view with blue, purple, &c. But in the acromatic teleſcope, the violet rays being moſt refrangible, are bent moſt in paſſing through the convex lens, and the red rays leaſt: in their paſſage through the concave part of this compound lens, the contrary effect takes place; ſo the greateſt and leaſt refrangible rays meet in a mathematical point, and, of courſe, render the field of view acromatic or colourleſs.

The *reflecting teleſcope* exceeds all others in its *magnifying power* and *portable ſize*; and its outward figure conſiſts of a great and ſmall tube, ſcrewed into the end of one another. At the bottom of the great tube is placed the large concave mirror, with a hole through its middle. Parallel rays from celeſtial objects falling on this mirror, are reflected back by it, and form the *image* a little ſhort of the *ſmall concave mirror* which faces the hole in the large one. From this image the rays diverge to the ſmall mirror, and are from thence reflected parallel, and inverted, into the ſmall tube, through the hole in the large mirror: Here meeting with a convex lens, they are ſo refracted as to form the image in the *ſmall tube*. The *image being now brought ſo near*, requires nothing but a ſingle or compound *eye glaſs* to ſend it duly magnified to the retina. Rays from any terreſtrial object *will not come parallel* but converge a little; hence the image is formed nearer the great mirror, and therefore a ſcrew is fixed to the ſmall mirror, on the outſide the tube, to adjuſt it to it; and alſo to the *greater or leſſer convexity* of different eyes. Dr. Herſchel's reflector is formed on the Newtonian plan, *i. e.* its great mirror is not perforated, and therefore its image is received by a plane mirror placed diagonally within the tube, and which ſends that image through the magnifying or microſcope part fixed perpendicularly in the tube. The excellence of this inſtrument conſiſts in the parabolic *curvature* and *poliſh* of its great mirror, which forms the image of the object looked at *ſo perfect*, that a magnifying power of 6500 can be applied to it.

This inſtrument is carried to a ſtill greater magnifying and diſtinct power, by a mirror of near five feet diameter, and of 40 feet focal length, without any obſtructing mirrors, ſo that the light, even from the moon, is too ſtrong for a naked eye to look at through it.

The *diagonal mirror*, for viewing prints, is a pleaſing inſtrument. If a *plane mirror* be placed at an angle of 45 degrees above a print lying horizontal and inverted, it will turn the rays reflected from the print into an horizontal direction to the eye: If then a *large convex lens* be placed between the eye and the mirror, the picture will be prodigiouſly magnified; and if an aſſemblage of *ſhell-work* environ the view between the *print and the mirror*, the picture will have a beautiful frame to it.

The *camera obſcura* is formed on the ſame principles. A *diagonal mirror* is ſet at the ſame angle againſt the landſcape, and reflects it downward through a *convex lens* into a *dark box*, where it is painted on a *white paper* placed in the focus of the lens, and on which a hand put into the box may draw the landſcape to the minuteſt exactneſs.

The *opera glaſs* was originally formed of a ſmall diagonal mirror, which ſends the rays through a convex glaſs to the eye. Through this a gentleman may look at a diſtant lady in the company, and the lady know nothing of it.

The *magic lanthorn* is formed on the ſame principles as the *ſolar microſcope*; a candle ſupplies the place of the ſun; and having its rays tinged with the colours of *tranſparent figures painted on glaſs*, throws them through two convex lenſes on a white wall in a dark room, prodigiouſly magnified. Argand's lamp has improved this inſtrument very much, as well as the lucernal microſcope, common illumination, the ſea lights of the Scilly Iſlands, invented by the Lecturer, &c.

END OF THE NINTH LECTURE.

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LECTURE X.

Uſe of the Globes.

WHEN a ſhip approaches us at ſea, the firſt part of her we ſee is her *upper ſails*, after that we ſee her *lower ſails*, and then the *hull:* 'Tis evident ſhe moves on a round ſurface, or we ſhould ſee the whole at a time. In ſailing from Capes we loſe ſight of them firſt at the *bottom*, then the *middle*, and at laſt the *top* diſappears. Theſe effects are in all parts of the world. Several perſons have ſailed round the earth. And all the bodies in the ſyſtem are round. Hence we conclude that the *earth is a globe* alſo.

The earth's roundneſs is no more affected by the largeſt mountains, than the roundneſs of a common globe is by a few grains of duſt thrown upon it; for they bear no greater proportion to its bulk. It is 7,970 miles in diameter: Near 100,000,000 of miles from the ſun: Moves round him in 365 days, 5 hours, and 49 minutes, at the rate of 60,000 miles an hour; and turns round upon its axis every 24 hours, from weſt to eaſt, which makes all the heavenly bodies ſeem to turn round the contrary way, or from eaſt to weſt.

The particles of which the earth is compoſed would fly into confuſion, if not held together, in the form of a globe, by the *power* of *gravitation*. 'Tis this power which gives *weight* to all bodies, or that tendency they have towards the centre of the earth. Hence the general *top* of the earth becomes its whole ſurface, and the general *bot-*

tom its centre. The *Antipodes* are, therefore, as much on the top as we. But as the parts of the earth are looſe, the violent motion it has on its axis will, in ſome degree, overpower even the force of gravity, and accumulate more matter round the *Equator*, becauſe the *centrifugal force* is greater there; hence the true figure of the earth is an *oblate ſpheroid*, or like an orange, 35 miles more in diameter at the equator than at the poles. This has been proved by actual menſuration, and is explained by the whirling rings.

This oblate figure proves its *diurnal motion*; if it were at reſt it would be neceſſarily a perfect ſphere. Its motion may be proved by letting bodies fall from leaning towers; from the Aſinelli Tower at Bologna (247 feet high) bodies fall 8½ lines to the eaſt of the plumb line. We perceive not this motion, becauſe the *air* in which we live, partaking of the general gravitation, is carried round along with the earth. When a ſhip turns round, if we look out at the cabin windows, we believe ourſelves at reſt, and the neighbouring country turning round us;—we are deceived in like manner in the motion of the earth.

Where there is no reflection from contiguous objects, a globe can but be *one half* enlightened by a luminous body; hence, if a globe turns round, there muſt be a ſucceſſion of light and darkneſs, or day and night, to its inhabitants.

Had a globe no other motion, there could be no variety in its ſeaſons or length of days. Gravity decreaſes as the ſquares of the diſtances increaſe: And if one body move in an oval, round another as its centre of motion, the ſquare of its periodical times will be as the cube of its diſtance from that body; this holds preciſely with regard to the planets and their moons. The planets ſometimes appear to *ſtand ſtill*, ſometimes to *go backwards*; this muſt always be the caſe where one body moves nearly in the ſame plane, and within the orbit of another moving body. —The eclipſes of Jupiter's ſatellites appear later to us by

16 minutes at one time of our year than at another. 'Tis matter of obſervation, that all the planets revolve round the ſun. From all which, we are certain that the earth goes round the ſun, and not the ſun round the earth.

We know the path our earth deſcribes in the heavens, by obſerving *that* which the ſun ſeems to deſcribe in the oppoſite part of the heavens. We find one ſtar without any apparent motion, ſituated 23 degrees and a half from the axis of this orbit, which is occaſioned by being nearly oppoſite to one of the poles of our earth, and thence called the polar ſtar; hence we diſcover that ſublime contrivance the inclined axis of the earth, which keeping always *parallel to itſelf*, occaſions the different ſeaſons, and different lengths of day and night; diffuſing equally, over the face of both hemiſpheres, the bleſſings of the ſun.

The axis ſo diſpoſed will neceſſarily bring the northern and ſouthern parts of the earth alternately to the ſun; therefore, when it is ſummer in the *north*, it will be winter in the *ſouth*, and vice verſâ. So far on each ſide the equator as the ſun at any time of the year ſhines vertically, is called the *torrid zone*, and it is bounded by two imaginary lines; *that* to the north, is called the *tropic of cancer*, and *that* to the ſouth, the *tropic of capricorn*. When the ſun ſhines vertically over the firſt, he muſt ſhine 23 degrees and a half further than the north pole, and will not therefore ſet for many days together to the inhabitants of the *north frigid zone*—but it will be then total darkneſs (the ſame time) to thoſe of the *ſouthern frigid zone*; hence the poles *muſt* but have one day and one night in the year. Theſe two zones (as they are called) are bounded by lines alſo, the north called the *arctic*, the ſouth the *antarctic* circle. The intermediate ſpaces, between the torrid and frigid zones, are called the *temperate zones*.

In the northern hemiſphere the *vernal equinox* (or equal day and night in the ſpring) is about the 20th of March;

and the *autumnal equinox* is about the 23d of September; in the ſouthern hemiſphere the contrary. At the equinoxes the ſun ſhines vertically over the equator; at the *ſolſtices* he ſhines 23 degrees and a half from the equator.

The *meridian* of any place is a ſemicircle paſſing through it, cutting the equator at right angles, and terminating in the poles. The earth's circumference is 360 degrees, each near 70 Engliſh miles, and as the earth turns round on its axis in 24 hours, each meridian revolves 15 degrees in an hour, for 24 × 15 = 360. Therefore every place to the *eaſtward* of another, has its hours ſooner, if *weſtward*, ſo much later.

The *longitude* of any place, is the number of degrees between its meridian and the meridian of any place from whence the longitude is reckoned, and is deemed *eaſt* or *weſt*, according as it is ſituated. The eclipſes of *Jupiter's ſatellites* afford a method of finding the longitude, thus: Suppoſe an eclipſe of any *ſatellite* happens in London at ſix in the morning, and that it is ſeen at another place at four in the morning, the difference of time is two hours, which anſwers to 30 degrees weſt of London. Theſe obſervations the motion of a ſhip hinders from being made at ſea; and hence may be perceived the extreme utility of a regular time-keeper.

The *latitude* of a place is ſo many degrees as it is from the equator; if to the north, it is ſaid to be in *north latitude*; if to the ſouth of the equator, in *ſouth latitude*; hence, by the lines of longitude and latitude, the face of a globe is covered with *imaginary ſquares*, and interſecting lines, by which the ſituation of every ſpot on the face of the earth is as exactly aſcertained, as the parts of an eſtate are by its hedges and ditches.

The *rational horizon* of a place, extends 90 degrees from that place on all ſides. The *ſenſible horizon* is the boundary of the obſerver's ſight on all ſides.

The *ecliptic* is that circle in the heavens through which the earth makes its revolution round the ſun; and it is diſtinguiſhed by conſpicuous aſſemblages of fixed ſtars, called ſigns or conſtellations, ſuch as *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, *&c.* The *zodiac* extends to eight degrees on each ſide the ecliptic, and with it round the heavens.

The four continents of the earth are, *Europe*, *Aſia*, *Africa*, and *America*. The oceans are the *Northern*, the *Atlantic*, the *Ethiopean*, the *Indian*, the *Pacific*, and the *Southern Oceans*. The unknown parts of the earth contain 160,566,276 ſquare miles; the inhabited parts 38,990,569 *i.e.* Europe 4,456,065; Aſia 10,798,823; Africa 9,654,807; America 14,110,874. In all 199,556,845; which is the number of ſquare miles on the whole ſurface of our globe.

When a round ball has the different countries, kingdoms, towns, and rivers, delineated upon it, agreeable to their ſituations, it is a repreſentation of the earth. If an hollow ſpherical ball could have the fixed ſtars properly marked on its inſide, with the ſun, moon, and planets, it would be a repreſentation of the heavens to an eye placed in its centre; but this being inconvenient, the fixed ſtars are placed on an opaque globe, and the ſun and planets repreſented by patches placed on the ecliptic, becauſe they are continually changing their places.

END OF THE TENTH LECTURE.

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LECTURE XI.

On the Moon, &c.

THE *moon* is no planet, but only a ſatellite, or an attendant on the earth. The farther any planet is from the ſun, the more occaſion it has for ſuch an help to its light; hence Mercury and Venus are without moons, as being near the ſun; but Jupiter has four, and Saturn ſeven, becauſe of their diſtance from it.

The moon's face abounds with great *inequalities*, and hence ſhe reflects a more chaſte and agreeable light than if her ſurface was ſmooth. She always keeps the *ſame face* towards us (ſome ſay becauſe the quality of that ſide of her is more adapted to catch the attraction of the earth than the other), and conſequently muſt turn once round her own axis, while ſhe goes once round the earth in her orbit. Her *periodical revolution*, or time of going round from one point of her orbit to the ſame point again, is 27 days 7 hours 43 minutes: But her *ſynodical revolution*, or time from change to change, is 29 days 12 hours 44 minutes;—this difference is cauſed by what the earth has advanced in the ecliptic during that time, which is 29 one-tenth degrees. *(Illuſtrated by the Orrery and Ferguſon's paradox.)*

The moon's mean diſtance, found by her parallax, is 240,000 miles. Her diameter is 2180 miles,—and ſhe moves about 2290 miles every hour.

The *moon* has no light of her own, but only reflects the beams of the ſun, as a poliſhed body does the light of a andle; hence, as ſhe is a globe, we muſt ſometimes ſee *more*, ſometimes *leſs*, of her enlightened ſide, *i. e.* when ſhe is between us and the ſun, her dark ſide is towards us, and therefore ſhe diſappears; as ſhe advances forward we ſee a ſmall part of her enlightened ſide, and call it the *new moon*; the next evening, ſhe is got a few degrees farther to the eaſt, and we ſee *more* of her illumined ſide;—every evening we find her advanced, till ſhe riſes in the eaſt in oppoſition to the ſun in the weſt, and then her whole enlightened ſide is towards us, and we ſay that ſhe is at the *full*; her decline is from the ſame reaſons; and a ball over a gate enlightened by the ſun conveys a clear idea of both. *(Illuſtrated by the Orrery.)*

The earth is a *moon* to the moon, waxing and waning as ſhe does; it appears 13 times as large to the Lunarians as the moon does to us, affording them both an uſeful and an amazing ſpectacle, for its continents and ſeas may be plainly perceived by them, as well as its rapid motion round its axis. *(Proved by the Orrery.)*

The planets as well as their ſatellites being *enlightened by the ſun*, muſt caſt *ſhadows* towards that part of the heavens oppoſite to the ſun. Was the earth bigger than the ſun, its ſhadow would ſpread and extend far beyond the orbit of Mars, and conſequently *eclipſe him*, for he is about 42 millions of miles from the earth, when they are in conjunction; but the earth's ſhadow never reaches him, therefore it muſt end in a *point* ſhort of that diſtance; another proof how much the ſun is bigger than the earth: but the moon is eclipſed when ſhe falls into the earth's ſhadow, which, for the reaſons above, can never happen but when ſhe is at the *full*, becauſe that is the only time when ſhe is oppoſite to him; but was ſhe a *luminous body*, ſhe could not be darkened by the earth's ſhadow.

The ſun is eclipſed when the moon paſſes directly between him and any part of the earth; this can only happen at the *change of the moon.*

Was the moon's orbit in the *plane* of the earth's path round the ſun, ſhe would be eclipſed every time ſhe came to the *full*, and would eclipſe the ſun every time ſhe came to the *change*; but one half of her orbit is on the *north ſide* of the ecliptic, and the other half on the *ſouth ſide* of it, and muſt therefore cut the ecliptic in two oppoſite points, called the *moon's nodes*. The angle of this orbit with the ecliptic is 5 degrees and one third. (*Shewn on the Orrery.*)

When the moon is at full, above 12 degrees from either of theſe nodes, ſhe paſſes clear of the earth's ſhadow, and cannot be eclipſed; and when ſhe changes above 18 degrees from either of them, ſhe paſſes either above or below the ſun, and therefore cannot eclipſe him: But if ſhe be at full or change within thoſe diſtances, then an eclipſe happens, and if ſhe be *in* the node, the eclipſe is central. (*Explained by the Orrery.*)

If theſe nodes kept always in the *ſame* ſigns of the ecliptic, the ſun and moon would always be eclipſed in the ſame *places*, and at the ſame *time*, every year:—but the eclipſes *fall back* every year from the eaſt to the weſt, in ſuch a manner, as to prove that the moon's orbit *moves backwards* 19 degrees one-third every year; ſo that in 18 years and 225 days, there is a return or reſtitution of the ſame eclipſes; and they then appear in the ſame places and the ſame time as before. (*Illuſtrated by the Orrery.*)

The earth and moon are chained to one another, as it were, by their *mutual attraction*, which, like the ſun and planets, is in proportion to their quantities of matter. If an heavy and a light ball be tied to the two ends of a ſtring a yard long, and toſſed up into the air, they will form to themſelves a centre of gravity. On this centre of gravity the earth and moon revolve in *equilibrio*, and its diſtance from their centres is inverſely as their quantities of matter, *viz.* 6000 miles from the earth's; conſequently the centre of gravity forms the *real orbit*, and makes the earth 12,000 miles nearer the ſun at the time of *full moon* than at the time of change. This is demonſtrable by the ſun's appearing ſo much larger at the full than at the change of the moon, as meaſured by a micrometer.

The further any part of the earth is from this centre of gravity, the greater is its tendency to fly off in a tangent; —therefore the *ſide of the earth* which is turned away from the moon has a greater *centrifugal motion* than its *centre* has: and this *centre* a greater than *the ſide* next the moon. At the earth's *centre*, the moon's attraction balances the centrifugal force, but muſt be *ſtronger* than the centrifugal force of the *ſide of the earth next her*, and *weaker* than the centrifugal force of the *ſide fartheſt from her*. As the moon's attraction is greater than the centrifugal force on that ſide of the earth next the moon, of courſe the *tide* will riſe on that ſide: But as the centrifugal force on the oppoſite ſide is greater than the moon's attraction, the tide will alſo riſe on that ſide; hence the reaſon of *two* tides in 25 hours. *(Proved by the tide table.)*

The ſun agitates the water in proportion to the moon, as 3 to 10; therefore, when the ſun and moon draw in the *ſame direction*, they cauſe a *ſpring tide*, and this happens at the change of the moon, If the earth had no moon, the ſun would cauſe a *ſmall tide* in the oceans, therefore, at the full of the moon ſpring tides happen as well as at the change, for the ſun's centrifugal tide being reinforced by the moon's attraction, and the moon's centrifugal tide by the ſun's attraction, ſpring tides happen both at full and change of the moon; but at the quarters, when they attract in *contrary directions*, they deſtroy the effects of each other in a degree, and then we have *neap tides*. At the *equinoxes* the ſun and moon being both on or near the equator, their attraction is more in a *line* than at moſt other ſeaſons, hence the *prodigious tides* which generally follow theſe ſeaſons, both in the air and ſea. A planet alſo falling in conjunction with the ſun and moon, will increaſe the tides ſtill more.

The *air* being a fluid much lighter than water, is more affected by the moon's attraction. Hence, at the full and change the barometer is moſt affected; and ſome ſay lunatics are more affected at thoſe ſeaſons; which, if ſo, muſt be by the ſpring tides of the air.

To the inhabitants ſituated at a conſiderable diſtance from the equator, the *different parts* of the ecliptic riſe at very *different angles* with the horizon. In northern latitudes, the ſigns *Piſces* and *Aries* riſe with the *ſmalleſt angles*; *Virgo* and *Libra* with the *greateſt*; therefore when the moon is in *Piſces* and *Aries*, ſhe muſt riſe nearly at the *ſame hour* for ſix or ſeven days together. In *winter* the moon is in thoſe ſigns about the time of her firſt quarter; but as ſhe muſt then riſe about *noon*, *that* riſing is not taken notice of. In *ſpring* the moon is in them about her *change*, but as ſhe then gives *no light*, her riſing is alſo unnoticed. In *ſummer* ſhe riſes in *Piſces* and *Aries*, in her *third quarter*, about twelve o'clock at night, conſequently the phænomenon is ſeldom *then* regarded; but in *autumn* thoſe ſigns are oppoſite the ſun, and therefore the moon muſt be *full* in them, and very uſefully for the farmers, riſes in their harveſt immediately after ſun-ſet for ſeveral evenings together, and thence acquires the name of the *harveſt moon*. *(Proved by the Orrery and Globe.)*

END OF THE ELEVENTH LECTURE.

LECTURE XII.

Aſtronomy.

THE planets are retained in their orbits by the *power of* gravity: but as the ſun is by far the largeſt body in our ſyſtem, if no other power acted on them, they would be *drawn down to the ſun.* All bodies therefore that move in a curve, as the planets do round the ſun, muſt be acted upon by *two principles*; and motion being *rectilineal*, we ſuppoſe the Almighty gave each planet this kind of impulſe at its creation, ſo that between one power *drawing to the centre*, and another *acting perpendicular to it*, the planets are impelled in elliptic orbits round the ſun, as a pebble tied to a mill-ſtone and thrown from the hand, would revolve round the mill-ſtone. An idea of this is given by a ball impelled ſingly in a ſquare in two directions, one perpendicular to the other; when they both act, they give the diagonal of the ſquare, &c.

Our ſyſtem muſt be conceived as within the concave ſphere ſeeming to be formed by the *fixed ſtars*, and the *ſun* as near the centre of it, an huge globe of fire, near a million of miles in diameter, and near 100 millions of miles from the earth, according to calculations made from the tranſits of Venus.—He turns round on his axis in 25 days and 8 hours, as may be ſeen by ſpots on his face; and was no doubt intended to give light, heat, and vegetation, to the ſeven primary and fourteen ſecondary planets which revolve round him.

All theſe planets move round the ſun from *weſt by ſouth to eaſt*, in orbits nearly circular, and almoſt in the ſame plane. The *comets* move in all manner of directions, in orbits which are very long ellipſes, much inclined to one another, and to all the orbits of the planets. The tails of comets are only thin vapours; for, if they were flame, no ſtar could be ſeen through them.

The time in which any planet goes round the ſun is the *length of its year*, and the time on which it turns round on its axis, is *the length of its day and night* taken together, as repreſented in the Orrery.

The neareſt planet to the ſun is *Mercury*; he goes round him in 87 days 23 hours, is about 3000 Engliſh miles in diameter, and diſtant from the ſun 42 millions of miles; he moves in his orbit about 100,000 miles every hour; the length of his days and nights is unknown, being but 56 times the ſun's apparent diameter from him; he ſets and riſes too near the ſun for any obſervations to be made of his ſpots.

Venus goes round the ſun in 224 days 17 hours; her diameter is near 7,900 miles, her diſtance from the ſun is 79 millions of miles, her hourly motion in her orbit is 69 thouſand miles, and ſhe has been ſaid to turn round on her axis in 24 days 8 hours of our time, though from her want of viſible ſpots, this diurnal motion is much doubted. By her axis inclining 75 degrees from a perpendicular to her orbit (agreeable to the older aſtronomers), ſhe has two ſummers and two winters at her equator.

Her orbit alſo deviates three one-half degrees from the plane of the ecliptic, ſo that ſhe has two nodes, or places, where ſhe croſſes the ecliptic, one in the 14th degree of Gemini, and the other in the 14th of Sagittarius. If the earth happens to be in thoſe ſigns when *ſhe* is, then we ſee her tranſit over the ſun's face, a phænomenon which happened the 1ſt of April, 1761, and gave the aſtronomers the opportunity of calculating the ſun's parallax, *viz.* 7″ 40‴ and of conſequence his diſtance, as well as that of the planets.

The *earth* is the next planet in the order of the ſyſtem.

Mars, ſtill higher in the ſyſtem, is 167,000,000 of miles diſtant from the ſun, moves at the rate of 47,000 miles an hour, goes round the ſun in 678 days, and turns round on his axis in 23 hours, 39 minutes, and 22 ſeconds, at a medium, according to Dr. Herſchel's obſervations on the ſpot on the face of Mars; though he obſerves his motion not to be regular. He is about one-fifth as large as our earth: his *red appearance* is ſuppoſed to be occaſioned by a groſs thick atmoſphere with which he is ſurrounded, and which is ſuppoſed to ſupply his want of a moon.

Jupiter, the largeſt of the planets, is 570,000,000 of miles diſtant from the ſun, and above 400,000,000 from our orbit; he moves round the ſun in about 12 years of our time, at the rate of 30,000 miles per hour; he is near 90,000 miles in diameter (*i. e.* near 1000 times as large as our earth), is accompanied by four moons, ſome bigger and ſome leſs than the earth, which revolve round him as our moon does round us; and the faint ſubſtances on his face, called his belts, are ſuppoſed to be parts of his atmoſphere drawn into lines by his exceedingly quick revolution on his axis, which is once in 9 hours 49 minutes. That axis being perpendicular to the plane of his orbit, prevents any variety in his ſeaſons, it being perpetual ſummer at his equator, and perpetual winter towards his poles.

Saturn, the ſecond in magnitude, and hitherto conſidered the moſt diſtant of all the planets, is 949 millions of miles from the ſun;—near 70,000 miles diameter; moves at the rate of 18,000 miles an hour;—but is too remote for his ſpots to be ſeen. He is equipt with *five moons* (Dr. Herſchel has ſeen two more) beſides a *broad luminous ring*, which alſo reflects the ſun's light ſtrongly upon him. This planet is near 30 of our years in making his revolution round the ſun.

The *Georgian Planet* (or rather the *Herſchel*), ſo called by its ingenious and indefatigable diſcoverer Dr. Herſchel, was firſt ſeen near one of the feet of Gemini; its year is calculated to be 82½ of ours, its diſtance twice that of Saturn from the ſun, and its ſize 100 times as large as our earth. It has two ſatellites; and more have been lately diſcovered.

Theſe calculations are the lateſt and moſt accurate that have been made; they are given in round numbers to eaſe the memory, and are founded on *mathematical* as well as *ocular* certainty.

By an *attempt* at the ſame kind of calculation to find the diſtance of the *fixed ſtars*, 'twas found *that the whole diameter of the earth's orbit would not make a parallax or angle with the neareſt of them!* Their diſtance therefore mnſt be inconceivably great. Light diminiſhing as the ſquares of the diſtances increaſe, the ſun's rays therefore cannot enlighten the fixed ſtars; and a teleſcope which magnifies 400 times does not ſenſibly magnify them; 'tis therefore highly probable they are *ſuns* like ours, ſhine by their own unborrowed luſtre, were not intended for our ſervice, but to give light, heat, &c. to ſyſtems of worlds of their own, formed probably for the ſame purpoſes as ours, though too remote for our eyes, aſſiſted by the beſt glaſſes, to perceive. We find the worlds of our ſyſtem revolve like the earth, and are covered with *continents*, *ſeas*, *hills*, *&c.* Who can doubt, therefore, but they are inhabited, as well as all the worlds of the other ſyſtems? How much too big is this idea for the human imagination! By the lately improved teleſcopes thirty thouſand of theſe ſuns have been found, more than the naked eye can perceive! Were our glaſſes ſtill better, we ſhould, no doubt, find more—'tis not improbable there may be ſtars ſo diſtant that their light has not reached the earth ſince the creation! Many of thoſe ſtars appear double, and coloured green, blue, red, violet, &c.

Let us on the wings of imagination then launch into the immenſity of ſpace, and behold *ſyſtem* beyond *ſyſtem*, *above us*, *below us*, to the *eaſt*, the *weſt*, the *north*, the *ſouth!* Let us go ſo far as to ſee our ſun but a *ſtar* among the reſt, and our ſyſtem itſelf as a point, and we ſhall but even then find ourſelves on the *confines of creation!* How inadequate then muſt be the utmoſt ſtretch of human faculties, to a conception of that amazing *Deity* who made and governs the whole! Should not the narrow prejudices, the littleneſs of human pride, ſoften into humility at this thought!

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EXPLANATION OF SUCH UNCOMMON WORDS AS CANNOT, WITHOUT AFFECTATION, BE OMITTED IN THIS COURSE.

A

ABSORB, to drink in.
Acid, any thing ſour.
Accelerated, haſtened, hurried forward.
Accumulate, to heap up.
Adheſion, the ſticking together.
Affinity, related to, having an affection for.
Alkali, fixed ſalt or ſubſtances efferveſcing with acids.
Analogy, likeneſs, proportion.
Apparatus, inſtruments for experiments.
Attraction, a drawing together.
Axis, an axle on which any thing turns.
Azote, the noxious part of the atmoſphere.

C

Carbon, charcoal.
Carbonic acid gas, fixed air.
Capillary, ſmall as an hair.
Calx, the earth or cinders of a metal.
Caloric, fire.
Centrifugal, a direction given to a body different from that inclining to the centre.
Centripetal, tending towards the centre.
Coheſion, clinging or ſticking together.
Collateral, lying ſide by ſide.
Compreſs, to ſqueeze together.
Concave, ſpherically hollow.
Condenſe, to bring the parts of matter cloſer together.
Contact, touching each other.
Convex, ſwelling ſpherically outwards.
Converge, to draw towards a point.
Cryſtallization, ſalts ſhooting into their uſual forms.
Cylinder, like a rolling ſtone.

D

Denſity, compactneſs, cloſeneſs.
Diagonal, the line running between the oppoſite corners of a ſquare.
Diverge, to ſpread out.

E

Ebullition, a bubbling like boiling water.
Elaſtic, having a ſpring.
Electrometer, an electrical gage.
Efferveſcence, a ferment or diſcharge of fixed air, a waxing hot.
Ellipſis, an oval line or ſurface.

F

Fibre, a ſmall ſtring.
Flaccid, lax, looſe, or flabby.
Fulcrum, a prop or point of ſupport.
Fluoric acid, acid of ſpar.
Frigorific, chill, or cauſing cold.

G

Gas, air.
Gravity, weight, or the tendency one body has to another.

H

Hemiſphere, half a globe.
Hermetically ſealed, tube cloſed with melted glaſs.
Hydrogen gas, inflammable air.
Hypotheſis, a ſuppoſition.

I

Immerſe, to dip or plunge in.
Impel, to drive onwards.
Incompreſſible, not to be ſqueezed into leſs compaſs.
Incidence, a falling or lighting on.
Inſulate, to cut off, like an iſland.
Interſtices, Intervals, or intermediate ſpaces.

L

Lateral, ſideway.
Longitudinal, lengthwiſe.

M

Medium, a means of conveyance.
Momentum, the moving force of a body.
Mephitic, poiſonous.
Muriatic acid, acid of ſea ſalt.

N

Nomenclature, a ſyſtem of relative names given to chemical ſubſtances.

O

Oblique, crooked, inclining.
Orbit, the tract deſcribed by a planet round the ſun.
Oxygen, principle of acidity.
Oxygen gas, dephlogiſticated air.
Oxyd, calx, ore, or reſiduum of a metal.

P

Particles, exceeding ſmall parts.
Percuſſion, ſtriking, or the effects of a ſtroke.
Perforate, to bore through.
Piſton, a moveable plug, juſt fitting a pipe.
Phænomenon, an appearance in nature.
Phlogiſton, formerly believed to be one of the principles of inflammability in bodies.
Pores, ſmall interſtices in bodies.
Preponderate, to deſcend, be heavier.
Projectile, a body in motion, caſt or thrown.

R

Rarefy, to thin, to make denſe matter weaker.
Reflection, rebounding back, returning.
Reciprocal, mutual, relative.
Refract, to incline, or break.
Reſervoir, a ciſtern, or head for a reſerve of water.
Reverberate, to beat back, to echo.
Rotation, returning about.

S

Saturation, abſorption, drinking in, &c.
Secrete, to ſeparate abſorb.
Senſorium, the ſeat of perception in the brain.
Solution, a ſolid diſſolved in a fluid.
Species, ſort or kind.
Specific, peculiar, bulk for bulk.
Spiral, like a rope coiled round.
Subterraneous, within the earth.
Sublimation, diſtillation of dry ſubſtances.
Sulphuric acid, oil of vitriol, or vitriolic acid.
Syphon, a bent tube, or crane.
Syſtem, compoſing a general ſtructure.

T

Tangent, a ſtraight line touching the circumference of a circle.
Tangible, capable of being felt or handled.
Tenacity, a clinging together.
Tenſion, a ſtretching out.
Tranſit, the paſſing of a planet before the face of another, or the ſun.
Tube, a pipe.

V

Vacuum, a ſpace devoid of air.
Valve, a trap door, letting a fluid come through, but not return.
Velocity, the moving ſpeed.
Vertex, the point at the top of any thing.
Vibrate, to ſwing as a pendulum.
Undulating, moving in waves.
Volatile, ſubject to evaporate or fly off.
Vis inertiæ, the tendency of all matter to continue in the ſtate it is in, whether of reſt or of motion.

FINIS.

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